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ShipMo3D Version 1.0 User Manual for Frequency Domain Analysis of Ship Seakeeping in a Seaway

Kevin McTaggart

Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2007-171
November 2007

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Abstract

This report serves as a user manual for frequency domain predictions of ship motions in waves using ShipMo3D Version 1.0. ShipMo3D is an object-oriented library with associated user applications for predicting ship motions in both the time domain and frequency domain. This report covers predictions in the frequency domain for a ship with nominally steady speed and heading, and a companion report serves as a user manual for predicting ship motions in the time domain for a freely maneuvering ship in calm water or in waves. Several ShipMo3D applications are used for obtaining ship motion predictions in the frequency domain. SM3DPanelHull creates a panelled representation of the ship hull using input offsets. SM3DRadDif generates a database of radiation and diffraction coefficients that contribute to the efficiency of subsequent computations. SM3DBuildShip creates a model of the ship, including required data for the hull geometry, radiation and diffraction properties, and appendage geometries. Motion predictions are obtained using SM3DSeakeepRegular, SM3DSeakeepRandom, or SM3DSeakeepSeaway, depending on the wave conditions for which ship motions are to be evaluated. SM3DTimeSeriesFromRaos produces ship motion time series from predicted motion response amplitude operators. SM3DPolarPlot produces polar plots of ship response as a function of ship speed and heading.

Résumé

Le présent rapport constitue un guide de l'utilisateur pour la prévision dans le domaine fréquentiel des mouvements de navires dans les vagues au moyen de ShipMo3D, version 1.0. ShipMo3D est une bibliothèque orientée objet dotée d'applications utilisateur connexes permettant de prévoir les mouvements des navires dans le domaine temporel et dans le domaine fréquentiel. Le présent rapport traite des prévisions dans le domaine fréquentiel pour un navire à vitesse et cap essentiellement stables, alors qu'un rapport complémentaire sert de guide de l'utilisateur pour la prévision des mouvements des navires dans le domaine temporel lorsque les navires manuvrent librement dans les eaux calmes ou dans les vagues. Plusieurs applications ShipMo3D contribuent à l'obtention de prévisions des mouvements des navires dans le domaine fréquentiel. SM3DPanelHull crée une représentation par panneaux de la coque du navire à partir de décalages d'entrée. SM3DRadDif produit une base de données contenant des coefficients de rayonnement et de diffraction, qui contribue à l'efficacité des calculs subséquents. SM3DBuildShip crée un modèle de navire intégrant les données requises sur la géométrie de la coque, les propriétés de rayonnement et de diffraction et la géométrie des appendices. Des prévisions de mouvements sont tirées de SM3DSeakeepRegular, SM3DSeakeepRandom ou SM3DSeakeepSeaway, se-

lon l'état des vagues pour lequel les mouvements des navires doivent être évalués. SM3DTimeSeriesFromRaos produit des séries temporelles de mouvements des navires à partir des opérateurs d'amplitude de réponse des mouvements prévus. SM3DPolar-Plot produit des tracés polaires de la réponse des navires en fonction de la vitesse et du cap des navires.

Executive summary

ShipMo3D Version 1.0 User Manual for Frequency Domain Analysis of Ship Seakeeping in a Seaway

Kevin McTaggart; DRDC Atlantic TM 2007-171; Defence R&D Canada – Atlantic; November 2007.

Introduction: ShipMo3D is an object-oriented library with associated user applications for predicting ship motions in calm water and in waves. Motion predictions are available in both the frequency domain and the time domain. For predictions in the frequency domain, a ship is assumed to travel with nominally steady speed and heading in waves. For predictions in the time domain, the ship can be freely maneuvering in either calm water or in waves. This report serves as a user manual for predicting motions in the frequency domain. A companion report provides a user manual for simulating motions in the time domain.

Principal Results: Several ShipMo3D applications are used for obtaining ship motion predictions in the frequency domain. SM3DPanelHull creates a panelled representation of the ship hull using input offsets. SM3DRadDif generates a database of radiation and diffraction coefficients that contribute to the efficiency of subsequent computations. SM3DBuildShip creates a model of the ship, including required data for the hull geometry, radiation and diffraction properties, and appendage geometries. Motion predictions are obtained using SM3DSeakeepRegular for regular waves, SM3DSeakeepRandom for a seaway with a principal wave direction, or SM3DSeakeepSeaway for a seaway defined by a directional wave spectrum in earth-fixed axes. SM3DTimeSeriesFromRaos produces ship motion time series from predicted motion response amplitude operators. SM3DPolarPlot produces polar plots of ship response as a function of ship speed and heading.

Significance of Results: ShipMo3D can now be used to produce frequency domain computations for ships in regular waves, in a random seaway with a principal wave direction, and in a seaway with a directional wave spectrum measured in earth-fixed axes. These computations can be used for various applications, including engineering analysis and development of operator guidance.

Future Plans: Additional ship motion prediction capabilities are being developed using ShipMo3D. The modelling of azimuthing propulsors, such as Z-drives, is being introduced. User applications are being developed for predicting motions of two ships in close proximity, including the modelling of hydrodynamic interactions.

Sommaire

ShipMo3D Version 1.0 User Manual for Frequency Domain Analysis of Ship Seakeeping in a Seaway

Kevin McTaggart ; DRDC Atlantic TM 2007-171 ; R & D pour la défense Canada – Atlantique ; novembre 2007.

Introduction : ShipMo3D est une bibliothèque orientée objet dotée d'applications utilisateur connexes permettant de prévoir les mouvements des navires dans les eaux calmes et dans les vagues. Des prévisions de mouvement sont possibles dans le domaine fréquentiel et dans le domaine temporel. Pour les prévisions dans le domaine fréquentiel, un navire est supposé se déplacer à une vitesse et à un cap essentiellement stables dans les vagues. Pour les prévisions dans le domaine temporel, le navire peut librement manoeuvrer dans les eaux calmes ou dans les vagues. Le présent rapport constitue un guide de l'utilisateur pour la prévision des mouvements dans le domaine fréquentiel. Un rapport complémentaire sert de guide de l'utilisateur pour la simulation des mouvements dans le domaine temporel.

Résultats principaux : Plusieurs applications ShipMo3D contribuent à l'obtention de prévisions dans le domaine fréquentiel. SM3DPanelHull crée une représentation par panneaux de la coque du navire à partir de décalages d'entrée. SM3DRadDif produit une base de données contenant des coefficients de rayonnement et de diffraction, qui contribue à l'efficacité des calculs subséquents. SM3DBuildShip crée un modèle de navire intégrant les données requises sur la géométrie de la coque, les propriétés de rayonnement et de diffraction et la géométrie des appendices. Des prévisions de mouvements sont obtenues au moyen de SM3DSeakeepRegular pour les vagues régulières, de SM3DSeakeepRandom pour une voie maritime à direction principale des vagues ou de SM3DSeakeepSeaway pour une voie maritime définie par un spectre de vagues directionnelles sur des axes terrestres fixes. SM3DTimeSeriesFromRaos produit des séries temporelles de mouvements des navires à partir des opérateurs d'amplitude de réponse des mouvements prévus. SM3DPolarPlot produit des tracés polaires de la réponse des navires en fonction de la vitesse et du cap des navires.

Importance des résultats : ShipMo3D peut maintenant produire, dans le domaine fréquentiel, des calculs portant sur des navires dans des vagues régulières, dans une voie maritime à vagues aléatoires caractérisées par une direction principale et dans une voie maritime à spectre de vagues directionnelles mesuré sur des axes terrestres fixes. Ces calculs peuvent servir à diverses applications, notamment aux analyses techniques et à la conduite des opérations.

Travaux ultérieurs prévus : On met actuellement au point des ressources supplémentaires de prévision des mouvements des navires au moyen de ShipMo3D. La modélisation des propulseurs orientables en azimut, par exemple à transmission en Z, fait son apparition. Des applications utilisateur sont mises au point pour la prévision des mouvements de deux navires rapprochés, y compris la modélisation des interactions hydrodynamiques.

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1 Introduction

This report describes the prediction of ship motions in the frequency domain using ShipMo3D applications. ShipMo3D is an object-oriented library with associated applications for predicting ship motions. ShipMo3D can compute forces on a ship and resulting motions in both the frequency and time domains. This report describes applications for predicting ship motions in the frequency domain. A companion report, Reference 1, is the user manual for simulation in the time domain using ShipMo3D. For each ShipMo3D application, user input is read from an ASCII input file. Each application produces an ASCII output file, and many applications also produce graphical output.

Several reports describe the theory behind ShipMo3D, and also give verification and validation of ShipMo3D results. References 2 and 3 describe the prediction of hull hydrodynamic forces. The modelling of seaways is described in Reference 4. Reference 5 covers appendage and viscous forces, which are important for predicting lateral plane motions. Validation results in Reference 6 show good agreement between ShipMo3D predictions and data from model tests and sea trials.

When predicting ship motions in the frequency domain, a ship is assumed to move with nominally steady speed and heading. If motions of a freely maneuvering ship are required, then the time domain applications described in Reference 1 are available.

Section 2 of this report gives an overview of predicting motions in the frequency domain using ShipMo3D. Section 3 describes coordinate systems used for motions and ship geometry. Sections 4, 5, and 6 describe the applications SM3DSeakeepRegular, SM3DSeakeepRandom, and SM3DSeakeepSeaway, which are used to predict motions in the frequency domain for various types of sea conditions. The post-processing program SM3DTimeSeriesFromRaos is described in Section 7, followed by SM3DPolarPlot in Section 8. Section 9 describes inputs for the rudder autopilot and Section 10 describes various inputs for seakeeping predictions in random seas. Final conclusions are given in Section 11. Annexes at the end of the report give input file descriptions and sample input and output files for the ShipMo3D applications.

2 Overview of Using ShipMo3D for Predicting Ship Motions in the Frequency Domain

When using ShipMo3D to predict frequency domain motions of a ship with nominally steady speed and heading, the following applications are used:

SM3DPanelHull Develops a model of the hull surface represented using triangular and quadrilateral panels. Also computes hydrostatic properties for submerged portion of hull.

SM3DRadDif Computes hydrodynamic added mass and radiation damping. Also computes forces due to incident and diffracted waves.

SM3DBuildShip Builds a model of the ship including all components relevant to predicting ship motions.

SM3DSeakeepRegular Computes frequency domain motions of ship in a regular seaway (waves of constant heading, frequency, and amplitude).

SM3DSeakeepRandom Computes frequency domain motions of ship in a random seaway, with sea direction considered relative to ship direction. A random seaway is considered to have a principal direction, and waves must be unidirectional or defined by a spreading function relative to the principal wave direction.

SM3DSeakeepSeaway Computes frequency domain motions of ship in a random seaway, with the seaway described in earth-fixed axes and ship heading given by absolute direction (relative to the ship heading north). A random seaway in earth-fixed axes can be unidirectional or can have arbitrary directional spreading.

SM3DTimeSeriesFromRaos Computes ship motions in the time domain based on response amplitude operators (RAOs) generated by SM3DSeakeepRegular, SM3DSeakeepRandom, or SM3DSeakeepSeaway.

SM3DPolarPlot Produces polar plots of ship response as a function of ship speed and relative sea direction.

Before predicting ship motions in the frequency domain, one must use the applications SM3DPanelHull, SM3DRadDif, and SM3DBuildShip to model the ship geometric and hydrodynamic properties. These applications are documented in Reference 1.

Frequency domain predictions are provided by SM3DSeakeepRegular, SM3DSeakeepRandom, and SM3DSeakeepSeaway. SM3DSeakeepRegular gives motion predictions

for a ship in regular sinusoidal waves, and is most likely to be used for validating ship motion predictions with experiments in regular waves. SM3DSeakeepRandom gives motion predictions for a ship in random waves with a principal sea direction. Within SM3DSeakeepRandom, a seaway spectrum is represented by a point wave spectrum and an optional spreading angle applied to a cosine-squared spreading function. Input, output, and computations with SM3DSeakeepRandom consider principal sea direction relative to the ship heading (180 degrees for head seas, 90 degrees for seas from port). SM3DSeakeepRandom is most likely to be used for general seakeeping and operability analysis. SM3DSeakeepSeaway gives motion predictions for a ship in a seaway described by a wave spectrum with a fixed orientation, such as a multi-directional wave spectrum that has been measured using a wave buoy or wave radar system. Input, output, and computations with SM3DSeakeepSeaway consider ship heading (0 degrees for the ship heading north). SM3DSeakeepSeaway is most likely to be used for comparing predictions with full-scale trials, and for real-time operator guidance systems. Section 6 describes SM3DSeakeepSeaway in greater detail.

Frequency domain predictions from SM3DSeakeepRegular, SM3DSeakeepRandom, and SM3DSeakeepSeaway are essentially linear; however, all three applications consider the nonlinear influence of roll motion amplitude on roll damping. ShipMo3D roll damping computations are described in detail in Reference 5. For SM3DSeakeepRegular, roll amplitude and associated roll damping are evaluated iteratively for each combination of ship speed, heading, wave frequency, and wave amplitude. For SM3DSeakeepRandom, RMS roll motion and associated roll damping are evaluated iteratively in long-crested seas for each combination of wave spectrum, ship speed, and heading. The following relationship is used for determining effective roll amplitude and associated roll damping in random seas:

$$|\eta_4| \;=\; 1.25\,\sigma(\eta_4) \tag{1}$$

where $|\eta_4|$ is roll amplitude used for roll damping computations and $\sigma(\eta_4)$ is RMS roll motion. For SM3DSeakeepSeaway, RMS roll motion and associated roll damping are evaluated iteratively in the specified wave spectrum for each combination of ship speed and absolute ship heading. Unlike SM3DSeakeepRandom, SM3DSeakeepSeaway considers the influence of short-crested waves when determining roll response amplitude operators (RAOs); however, roll RAOs from SM3DSeakeepSeaway can only be considered valid for the specific combination of fixed wave spectrum, ship speed, and absolute ship heading.

Predicted ship motion RAOs from SM3DSeakeepRegular, SM3DSeakeepRandom, or SM3DSeakeepSeaway can be used for generating time series of ship motions with SM3DTimeSeriesFromRaos. Alternatively, time series of ship motion can be generated directly using SM3DFreeMo, which is described in Reference 1. SM3DPolarPlot can produce polar plots of ship response as a function of ship speed and heading, and can be useful for applications such as operator guidance and operability analysis.

ShipMo3D applications use 3 main types of files. User input data are read from input files with names ending with ".inp". Application output data for review by the user are written to output files with names ending with ".out". Transfer of data between applications is done using files in Python pickle format, with names ending with ".pkl".

Each ShipMo3D application has default file names for input and output. Prefixes can be added to default file names by typing "-p PREFIX" or "--prefix=PREFIX" as command line options, where PREFIX is the specified file name prefix (e.g, the ship name). Alternatively, full input and output file names can be specified on the command line. Input file names can be specified by typing either "-i INFILE" or "--input=INFILE" as command line options, where INFILE is the specified input file name. Similarly, output file names can be specified by typing "-o OUTFILE" or "--output=OUTFILE" as command line options, where OUTFILE is the specified output file name. The command line options "-h" and "--help" show any command line arguments associated with a ShipMo3D application.

ShipMo3D user input files are in ASCII format. Each input line begin typically begins with a tag denoting the contents of the input line. Comments can be inserted into a file using the character "#" to denote a comment line or the beginning of a comment after other input on a line. An exclamation mark "!" denotes that an input line is continued on the next line. Here is some sample input demonstrating the usage of the comment and continuation characters:

```
# Sample input from a SM3DSeakeepRegular input file.
seaDirsDeg 0.0 15.0 30.0 45.0 60.0 75.0 90.0 105.0 !
           120.0 135.0 150.0 165.0 180.0
```

ShipMo3D applications include capabilities for plotting various entities, such as a panelled hull or results of radiation computations. Table 1 shows the various plot file formats available. Among the various plot file formats, the png format is very effective for storing complex colour plots using minimal file size.

Table 1: *ShipMo3D Plot File Formats*

bmp	Windows bitmap
eps	encapsulated PostScript
gif	graphics interchange format
pdf	Portable document format
png	portable network graphics
ppm	portable pixmap
ps	PostScript
svg	scaleable vector graphics
tiff	tagged image file format
wmf	Windows metafile

3 Coordinate Systems

ShipMo3D uses both earth-fixed and translating earth coordinate systems. Ship motions in the frequency domain are solved in the translating earth coordinate system shown in Figure 1. All ship motions in the frequency domain are given relative to their equilibrium values in calm water.

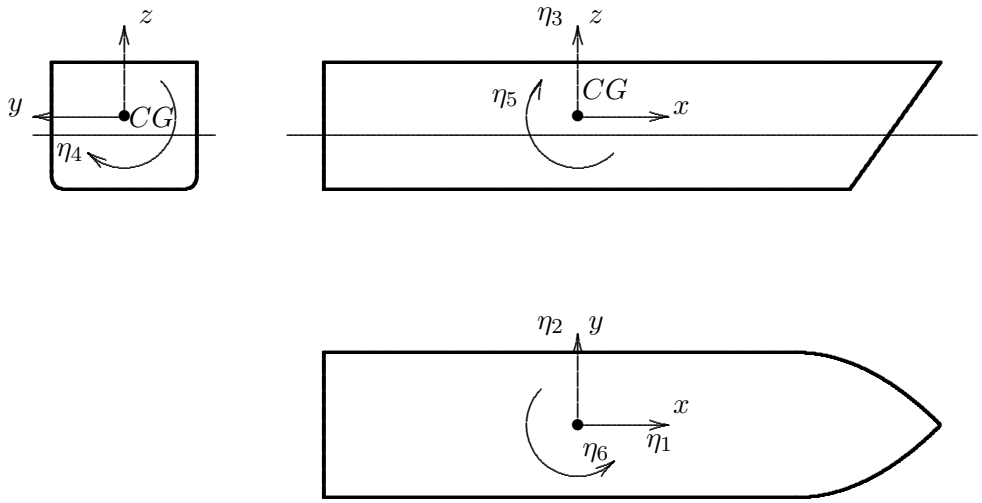

Figure 1: *Translating Earth Coordinate System*

When computing motions in the frequency domain, relative sea direction β_s is specified according to Figure 2, with a sea direction of 180° representing head seas.

Some familiarity with the ShipMo3D earth-fixed coordinate system of Figure 3 is required when using SM3DSeakeepSeaway, which computes frequency domain motions in a seaway defined in earth-fixed coordinates. The location of the ship centre of gravity in the horizontal plane is given by x^f, y^f. The direction ν of incident waves is given using a "from" convention, with 0° representing waves from north and 90° representing waves from east. Ship heading χ is given using a "to" convention, with 0° representing the ship heading north and 90° representing the ship heading east. Relative sea direction is related to ship heading and wave heading by:

$$\beta_s \;=\; \nu \;+\; 180^\circ \;-\; \chi \tag{2}$$

For deflections of rudders, ShipMo3D uses a convention of positive deflection when counter-clockwise as viewed from inside the hull. Consequently, positive deflection of a typical ship rudder pointing downward will cause a ship to turn starboard.

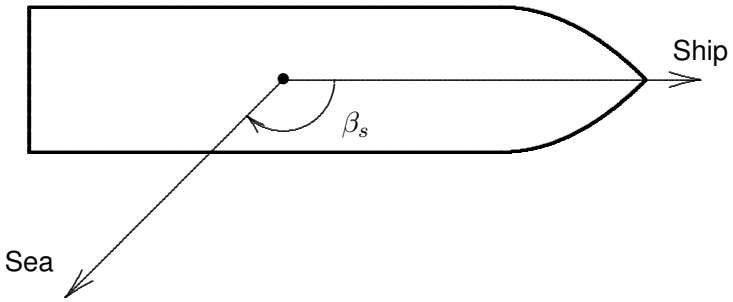

Figure 2: *Sea Direction Relative to Ship*

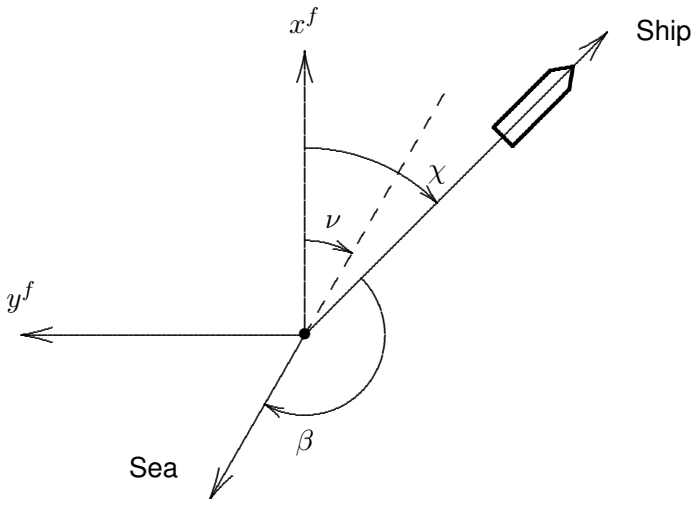

Figure 3: *Earth-Fixed Coordinate System*

4 Ship Seakeeping in a Regular Seaway - SM3DSeakeepRegular

Table 2 gives a summary of application SM3DSeakeepRegular. The most challenging aspect of using SM3DSeakeepRegular is the creation of the ship file using SM3DBuildShip, which is described in Reference 1.

Table 2: *SM3DSeakeepRegular Summary*

Purpose:	Computes ship motions in the frequency domain for a ship in regular waves.
Run time:	A few seconds.
Default input file:	seakeepRegular.inp
Default output file:	seakeepRegular.out
Input format and sample files:	Annex A
Other required input:	A frequency domain ship file created by SM3DBuildShip [1].

5 Ship Seakeeping in a Random Seaway with Principal Direction Given Relative to the Ship - SM3DSeakeepRandom

Table 3 gives a summary of application SM3DSeakeepRandom.

Table 3: *SM3DSeakeepRandom Summary*

Purpose:	Computes ship motions in the frequency domain for a ship in random waves with a principal sea direction (i.e., long-crested waves or waves with a cosine-squared spreading function).
Run time:	A few seconds.
Default input file:	seakeepRandom.inp
Default output file:	seakeepRandom.out
Input format and sample files:	Annex B
Other required input:	A frequency domain ship file created by SM3DBuildShip [1].

6 Ship Seakeeping in a Fixed Seaway with Ship Heading Given Relative to Earth-Fixed Axes - SM3DSeakeepSeaway

Table 4 gives a summary of application SM3DSeakeepSeaway.

Table 4: *SM3DSeakeepSeaway Summary*

Purpose:	Computes ship motions in the frequency domain for a ship in a fixed seaway, with ship heading given relative to earth-fixed axes.
Run time:	Ranging from a few seconds to several minutes.
Default input file:	seakeepSeaway.inp
Default output file:	seakeepSeaway.out
Input format and sample files:	Annex C
Other required input:	A frequency domain ship file created by SM3DBuildShip [1].

7 Time Series of Ship Motions from Response Amplitude Operators - SM3DTimeSeriesFromRaos

Table 5 gives a summary of application SM3DTimeSeriesFromRaos.

Table 5: *SM3DTimeSeriesFromRaos Summary*

Purpose:	Computes ship motions in the time domain for a ship with quasi-steady speed and heading
Run time:	A few seconds.
Default input file:	timeSeriesFromRaos.inp
Default output file:	timeSeriesFromRaos.out
Input format and sample files:	Annex D
Other required input:	A database of ship RAOs created by SM3DSeakeepRegular, SM3DSeakeepRandom, or SM3DSeakeepSeaway. A seaway model created by SM3DBuildSeaway [1].

8 Polar Plots of Ship Responses - SM3DPolarPlot

Table 6 gives a summary of application SM3DPolarPlot.

Table 6: *SM3DPolarPlot Summary*

Purpose:	Produces plots of ship responses as a function of ship speed and heading.
Run time:	A few seconds.
Default input file:	polarPlot.inp
Default output file:	polarPlot.out
Input format and sample files:	Annex E
Other required input:	None.

9 Inputs for Rudder Autopilot

For applications SM3DSeakeepRegular, SM3DSeakeepRandom, and SM3DSeakeep-Seaway, the user can specify input autopilot settings. If autopilot settings are not given as input for these applications, then default settings are used from the ship model produced by SM3DBuildShip [1].

For time domain simulation, ShipMo3D models a proportional-integral-derivative (PID) autopilot. For frequency domain computations, integral gains are assumed to be zero and the command rudder angle δ_C^{rudder} is evaluated as follows:

$$\delta_C^{rudder} \;=\; \sum_{j=1}^{6} \left[k_{\delta j}^{P} \left(\eta_j^f - \eta_{Cj}^f \right) \;+\; k_{\delta j}^{D} \dot{\eta}_j^f \right] \tag{3}$$

where $k_{\delta j}^P$ is the proportional gain for mode j, η_j^f is the displacement in earth-fixed axes for mode j, η_{Cj}^f is the command displacement in earth-fixed axes for mode j, $k_{\delta j}^D$ is the derivative gain for mode j, and $\dot{\eta}_j^f$ is the velocity in velocity in earth-fixed axes for mode j. Based on the command rudder angle evaluated above, the rudder response is given by:

$$\ddot{\delta}^{rudder} \;+\; 2\,\zeta_\delta\,\omega_\delta^{rudder}\,\dot{\delta}^{rudder} \;+\; \omega_\delta^2\,\delta^{rudder} \;=\; \omega_\delta^2\,\delta_C^{rudder} \tag{4}$$

where $\ddot{\delta}^{rudder}$ is rudder acceleration, ζ_δ is the nondimensional damping response constant, ω_δ is the rudder response natural frequency, and $\dot{\delta}^{rudder}$ is rudder velocity. Rudder deflections have a convention of positive for counter-clockwise deflection viewed from inside the hull.

For all ShipMo3D user applications, user input autopilot gains are based on earth-fixed coordinates; thus, input yaw gains are based on yaw being positive clockwise when viewed from above. For modelling of a conventional downward rudder using ShipMo3D, the input yaw displacement gain and yaw velocity gain will typically have values equal to or less than zero. Note that input surge and sway gains should be set to zero.

10 Inputs for Ship Motion Predictions in Random Seas

This section gives background information that is useful when running the applications SM3DSeakeepRandom and SM3DSeakeepSeaway, which both predict motions in random seas.

10.1 Wave Spectra

SM3DSeakeepRandom and SM3DSeakeepSeaway have a variety of different wave spectra that can be used for modelling seaways. Reference 4 describes modelling of seaways in detail. Wave spectra available in SM3DSeakeepRandom and SM3DSeakeepSeaway are provided here for reference. For point wave spectra (i.e., non-directional spectra), ShipMo3D uses units of $m^2/(rad/s)$ for spectral density. For directional wave spectra, ShipMo3D uses units of $m^2/(rad/s)/deg$ for directional spectral density.

10.1.1 Bretschneider Spectrum

The Bretschneider spectrum is the most commonly used model of point wave spectra in the open ocean. Based on the 15th International Towing Tank Conference (ITTC) [7], the formulation for the Bretschneider spectrum is:

$$S_{\omega_I}(\omega_I) = \frac{486.0\ H_s^2}{T_p^4\ \omega^5}\ \exp\left[\frac{-1948.2}{T_p^4\ \omega_I^4}\right] \tag{5}$$

where S_{ω_I} is spectral density, ω_I is incident wave frequency, H_s is significant wave height, and T_p is peak wave period. For the peak wave period, the following relations exist with the average and zero-crossing wave periods:

$$T_1 = 0.773\ T_p \tag{6}$$

$$T_z = 0.710\ T_p \tag{7}$$

where T_1 is the average wave period and T_z is the zero-crossing period.

10.1.2 Three Parameter JONSWAP Spectrum

The JONSWAP spectrum models relatively high-peaked point spectra typically encountered in fetch-limited regions [7]. The JONSWAP spectrum is obtained by multiplying the Bretschneider spectrum by a peak enhancement factor accounting for

fetch-limited conditions, giving the following [8]:

$$S_{\omega_I}(\omega_I) = \alpha^* \, H_s^2 \, \frac{\omega_p^4}{\omega^5} \, \exp\left[-1.25\frac{\omega_p^4}{\omega^4}\right] \, \gamma^{\kappa} \tag{8}$$

$$\kappa = \exp\left[\frac{-(\omega-\omega_p)^2}{2\sigma^2\omega_p^2}\right] \tag{9}$$

$$\sigma = \begin{cases} 0.07 & \text{for } \omega \leq \omega_p \\ 0.09 & \text{for } \omega > \omega_p \end{cases} \tag{10}$$

where ω_p is the peak wave frequency and γ is an input spectral peak enhancement parameter. Goda [9] derived the following approximate expression for the normalization term α^*:

$$\alpha^* = \frac{0.0624}{0.230 + 0.0336\,\gamma - 0.185/(1.9+\gamma)} \tag{11}$$

The JONSWAP spectrum is often presented as a two parameter spectrum, with the spectral peak parameter γ having a default value of 3.3.

10.1.3 Ochi and Hubble Six Parameter Spectrum

The Ochi and Hubble 6 parameter point spectrum [10] models collinear swell and sea components as follows:

$$S_{\omega_I}(\omega_I) = \frac{1}{4} \sum_{i=1}^{2} \frac{\left[\left(\frac{4\lambda_i+1}{4}\right) \omega_{p-i}^4\right]^{\lambda_i} \; h_{s-i}^2 \; \exp\left[-\left(\frac{4\lambda_i+1}{4}\right)\left(\frac{\omega_{p-i}}{\omega}\right)^4\right]}{\Gamma(\lambda_i)\,\omega^{(4\lambda_i+1)}} \tag{12}$$

where λ_i, h_{s-i}, and ω_{p-i} are the spectral shape parameter, significant wave height, and peak frequency for component i. The term $\Gamma(\lambda_i)$ is the Gamma function with argument λ_i. If only one of the two components is considered and the shape parameter λ_i equals one, then the six parameter spectrum is equivalent to the Bretschneider spectrum.

10.1.4 Bretschneider or JONSWAP Spectrum with Cosine-Squared Spreading Function

A directional wave spectrum can be most easily modelled by multiplying a point spectrum by a directional spreading function as follows:

$$S_{\omega_I,\nu}(\omega_I,\nu) = S_{\omega_I}(\omega_I)\, G(\nu) \tag{13}$$

where $G(\nu)$ is a directional spreading function. ShipMo3D can apply cosine-squared spreading function to a Bretschneider or JONSWAP spectrum. The form of the spreading function is as follows:

$$G(\nu) = \frac{1}{\theta_s} \cos^2\left(\frac{\nu - \overline{\nu}}{\gamma_s} \frac{\pi}{2}\right) \qquad \text{for } |\nu - \overline{\nu}| \leq \gamma_s \tag{14}$$

$$G(\nu) = 0 \qquad \text{for } |\nu - \overline{\nu}| > \gamma_s \tag{15}$$

where $\overline{\nu}$ is the principal wave direction and θ_s is the spreading angle in degrees. A spreading angle of 90 degrees is often used for seakeeping computations. The spreading function given in Equation (14) has units of deg^{-1} when the terms ν, $\overline{\nu}$, and θ_s are given in units of degrees. Although Equations (14) and (15) are defined using directions ν and $\overline{\nu}$ based in fixed-earth axes, they can also be easily defined in terms of relative sea direction β_s.

10.1.5 Ten Parameter Directional Spectrum

Directional seas can be most apparent when sea and swell components are similar in magnitude and are approaching from different directions. The ten parameter spectrum developed by Hogben and Cobb [11] is a directional extension of the Ochi and Hubble six parameter spectrum, with each of the swell and sea components being multiplied by its own directional spreading function as follows:

$$M_i(\nu) = A(P_i) \cos^{2P_i}\left(\frac{\pi}{180^\circ} \frac{\nu - \overline{\nu}_i}{2}\right) \text{ for } i = 1, 2 \tag{16}$$

where P_i and $\overline{\nu}_i$ are the directional spreading parameter and mean direction (from) for component i. The normalization factor $A(P_i)$ is expressed as:

$$A(P_i) = \frac{2^{(2P_i-1)}\,\Gamma^2(P_i+1)}{180^\circ\,\Gamma(2P_i+1)} \qquad i = 1, 2 \tag{17}$$

where $\Gamma(2P_i+1)$ is the Gamma function with argument $2P_i+1$. The above equations are based on parameters ν and $\overline{\nu_i}$ being in units of degrees, and each spreading function $M_i(\nu)$ having units of degrees^{-1}.

10.2 Motion-Induced Interruptions

SM3DSeakeepRandom and SM3DSeakeepSeaway can compute ship-referenced forces and estimate the incidence of motion-induced interruptions (MIIs) at seakeeping positions. The incidence of MIIs, which can be tipping or sliding events, is estimated using tipping or sliding estimator functions which include the contributions of vertical forces as well as the forces parallel to the deck. Detailed treatment of MIIs is given in References 12 and 13.

The incidence of tipping events for a person or object depends upon the tipping coefficient s/h, where s is the half stance width and h is the height above deck of the centre of gravity, as shown in Figure 4. The tipping coefficient is usually dependent upon the direction of tipping. To evaluate the incidence of sliding events, the tipping coefficient s/h can be replaced by the static coefficient of friction μ_s. Table 7 gives representative tipping and sliding coefficients from Reference 13 and unpublished data. The wide range of friction coefficients suggests the incidence of sliding can vary greatly, depending on sliding surface conditions. Because the static coefficient of friction for a person is usually greater than the tipping coefficient, a person will usually tip more easily than slide. Table 8, reproduced from Reference 12, gives risk levels associated with motion-induced interruptions (MIIs).

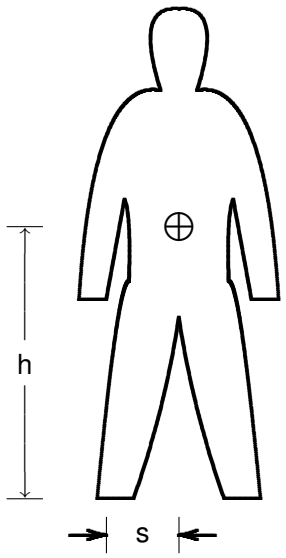

Figure 4: *Model for Person Standing on Deck*

Table 7: *Representative Tipping and Sliding Coefficients*

Tipping in the forward direction	0.17
Tipping in the sideways direction	0.25
Sliding, person standing on dry deck	0.7
Sliding, chair on interior floor	0.19
Sliding, helicopter for various deck conditions	0.2 - 0.8

Table 8: *MII Risk Levels*

Risk Level	MIIs per Minute
1. possible	0.1
2. probable	0.5
3. serious	1.5
4. severe	3.0
5. extreme	5.0

10.3 Slamming Pressures and Forces

Slamming calculations within ShipMo3D are based largely on the work of Ochi and Motter [14] and Stavovy and Chuang [15]. The maximum slam pressure at the keel is related to a sectional slamming pressure coefficient as follows:

$$p_{max} = \frac{1}{2}\,\rho\,V_r^2 \times \text{slamPressureCo} \tag{18}$$

where ρ is water density, V_r is the relative impact velocity upon impact, and slamPressureCo is the slamming pressure coefficient, which can be given as an input parameter or computed based on input geometry. For calculating slamming force per unit length, ShipMo3D uses the assumption from Reference 14 that the sectional slamming pressure goes from a maximum value at the keel to zero at a specified elevation above the keel, as illustrated in Figure 5. The elevation of zero slam pressure is typically taken as being 1/10 the sectional draft above the keel. The sectional slamming force per unit length is computed using an effective slamming pressure width as follows:

$$F_{max} = p_{max} \times \text{slamForceWidth} \tag{19}$$

where slamForceWidth is given as an input parameter or computed based on sectional geometry.

The user can provide input values for the slamming pressure coefficient and effective force width. Alternatively, ShipMo3D can compute the pressure coefficient and effective width based on the lower sectional geometry provided by the user. If the geometry is input as a wedge as shown in Figure 6, then ShipMo3D uses a fit to experimental data given by Stavovy and Chuang for computing the form factor. Stavovy and Chuang's method has been slightly modified to impose a form factor limit of 100, which affects sections with deadrise angles smaller than 6 degrees. Using the assumed pressure distribution of Figure 5, the effective pressure width for a wedge is:

$$\text{slamForceWidth} = \frac{\text{slamForceHeight}}{\tan(\text{deadRiseDeg})} \tag{20}$$

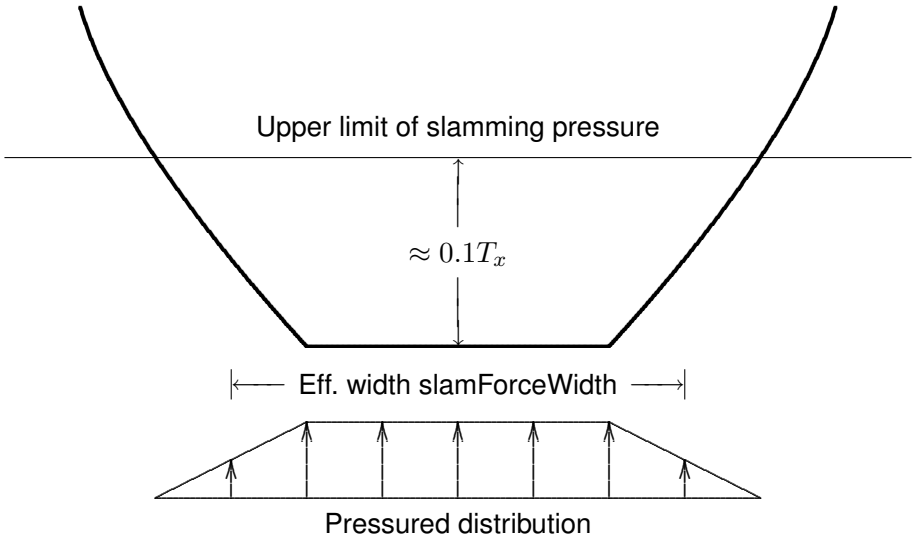

Figure 5: *Assumed Slamming Pressure Distribution for Sectional Force Computation*

where slamForceHeight is the height above the keel at which the slamming pressure goes to zero and deadRiseDeg is the deadrise angle.

If the user inputs the geometry near the keel as offsets, then ShipMo3D uses Ochi and Motter's method to compute slamming form coefficients. Figure 7 illustrates input offsets for computing the slamming form factor.

Experimental results indicate that slamming pressures can be highly sensitive to ship section geometry, size of area of pressure measurement, and structural properties of impact area; thus, predicted slamming pressures and forces should be considered to be only approximate values. Published values indicate that slamming form factors can lie within an extremely large range of between less than 1 and greater than 300; however, the actual slamming coefficient for a ship section in a seaway will rarely exceed 30. Slamming coefficients computed using input offsets near the keel and Ochi and Motter's method are likely smaller in magnitude and more realistic than values computed for a wedge based on Stavovy and Chuang. Figure 8 shows slamming coefficients predicted by ShipMo3D for wedge sections based on Stavovy and Chuang's method and Ochi and Motter's method. For wedge sections with large deadrise angles (greater than 50 degrees), Ochi's method fails to provide results because of numerical problems.

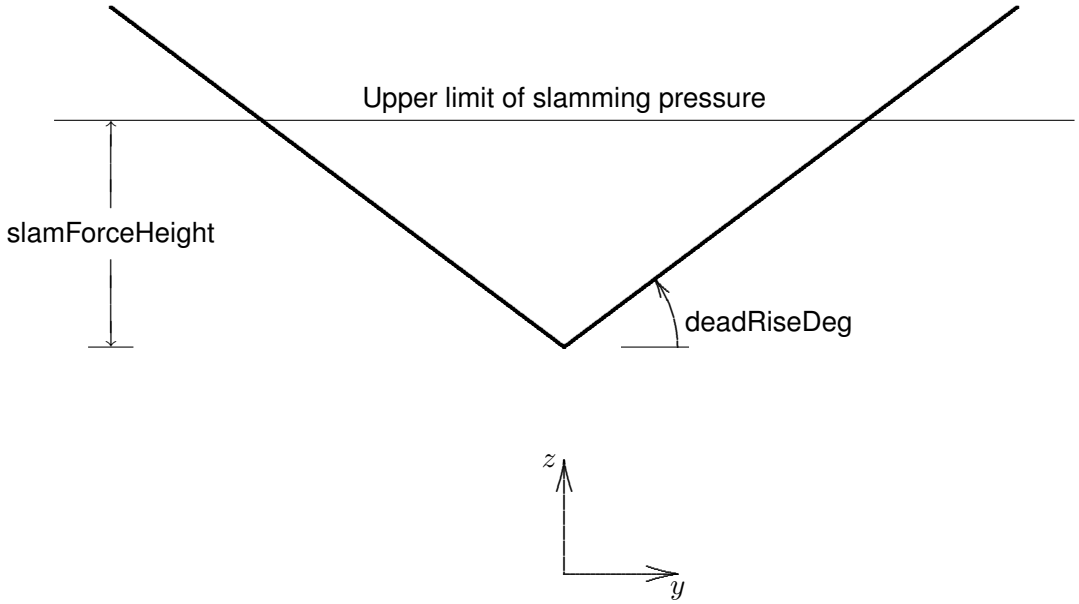

Figure 6: *Input Wedge Geometry for Computing Slamming Form Factor*

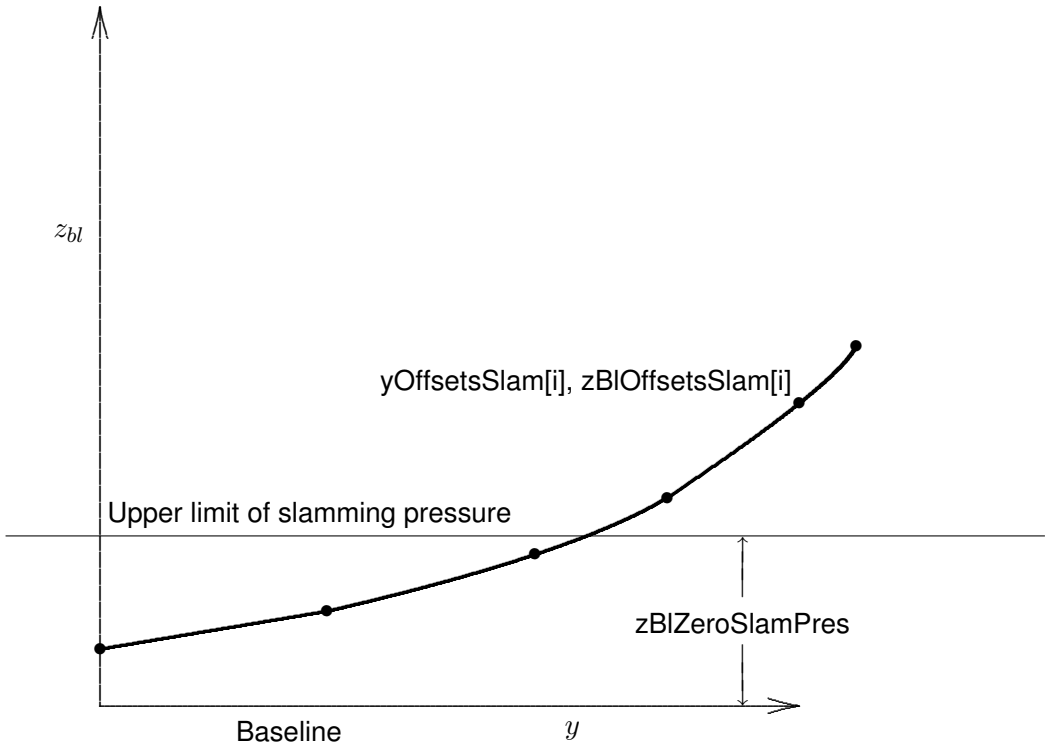

Figure 7: *Input Sectional Offsets Near Keel for Computing Slamming Form Factor*

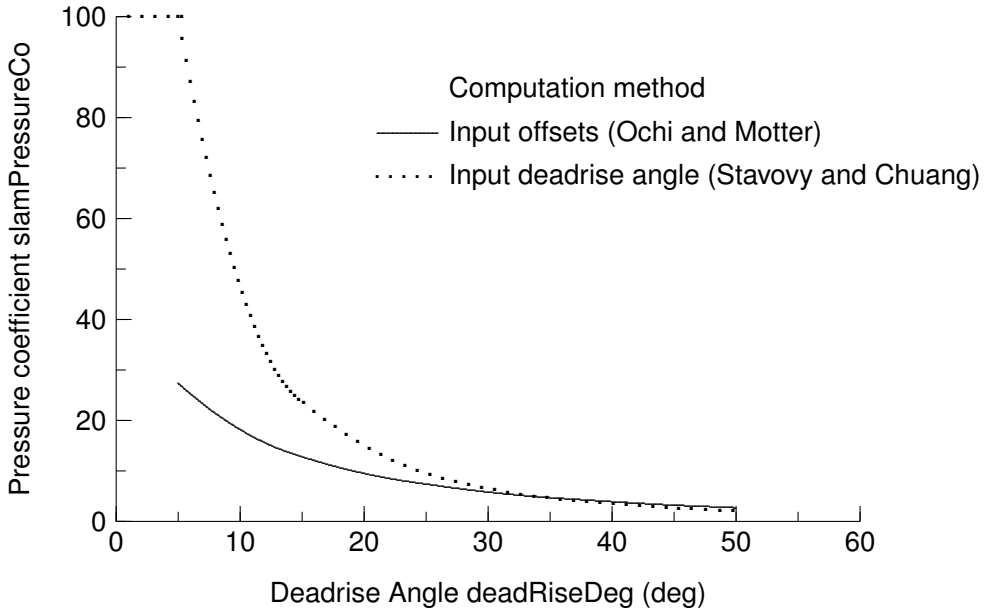

Figure 8: *Slamming Pressure Coefficients for Wedge Sections*

11 Conclusions

ShipMo3D user applications are now available for predicting motions in the frequency domain for a ship travelling with quasi-steady speed and heading in waves. A separate user manual [1] describes time domain simulation of motions for a freely maneuvering ship in calm water or in waves.

References

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Symbols and Abbreviations

$A(P_i)$	normalization factor for ten parameter spectral component i
F_{max}	maximum slamming force
$G(\nu)$	directional wave spectral spreading function
H_s	significant wave height
h	height above deck of the person or object centre of gravity
h_{s-i}	significant wave height for spectral component i
$k_{\delta j}^D$	autopilot derivative (velocity) gain for mode j
$k_{\delta j}^P$	autopilot proportional (displacement) gain for mode j
MII	motion-induced interruption
$M_i(\nu)$	directional spreading function for ten parameter spectrum component i
P_i	directional spreading parameter for ten parameter spectrum component i
p_{max}	maximum slamming pressure
RAO	response amplitude operator
RMS	root mean square
s	half stance width for computing MIIs
T_p	peak wave period
T_x	sectional draft
T_z	zero-crossing period
T_1	average wave period
$S_{\omega_I}(\omega_I)$	point wave spectral density
$S_{\omega_I,\nu}(\omega_I,\nu)$	directional wave spectral density
V_r	relative vertical velocity
x^f, y^f	horizontal plane coordinates in earth-fixed axes
α^*	JONSWAP spectrum normalization term
β	sea direction relative to ship
$\Gamma(X)$	Gamma function with argument X
γ	spectral peak enhancement parameter
δ^{rudder}	rudder deflection angle
ζ_δ	rudder nondimensional damping response constant
η_j	displacement in translating earth axes for mode j
η_j^f	displacement in earth-fixed axes for mode j
η_{Cj}^f	command displacement in earth-fixed axes for mode j

θ_s spreading angle for cosine squared spectral spreading

κ JONSWAP spectrum exponent

λ_i spectral shape parameter for spectral component i

μ_s static coefficient of friction

ν wave direction (from) in earth-fixed axes

$\overline{\nu}$ mean wave direction (from) in earth-fixed axes

$\overline{\nu}_i$ mean wave direction (from) for spectral component i

ρ water density

σ standard deviation (also RMS) or JONSWAP spectrum parameter

χ ship heading (to) in earth-fixed axes

ω_I incident wave frequency

ω_p peak wave frequency

ω_{p-i} peak wave frequency for spectral component i

ω_δ rudder response natural frequency

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Annex A: Files for Motions in a Regular Seaway with SM3DSeakeepRegular

A.1 Format of Input File for SM3DSeakeepRegular

Record (a), Beginning Record

"begin SM3DSeakeepRegular" (1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for run. This can include spaces.

Record (c), Input Ship Database File Name

"steadyShipDBFDFileName", steadyShipDBFDFileName (2 character strings)

"steadyShipDBFDFileName"	Record tag.
steadyShipDBFDFileName	Name of input ship database file in Python pickle format. This file must have been created using program SM3DBuildShip.

Record (d), Ship Loading Condition

"loadCondition", waterDensity, draftBlMid, trimBlStern, shipKG, correctionGM (1 character string, 5 floats)

"loadCondition"	Record tag.
waterDensity	Water density ρ (kg/m^3).
draftBlMid	Draft of baseline at midships (m).
trimBlStern	Trim of baseline by stern (m).
shipKG	Height of centre of gravity above baseline (m).
correctionGM	Correction to metacentric height (m).
Note:	The values in this record must agree with the values used for the ship database file specified in Record (c). Values are considered to be in agreement when they are within a tolerance of 0.001 kg/m^3 for density, and 0.001 m for draft, trim, height of CG, and metacentric height. The output file from SM3DBuildShip gives the values of the above parameters.

Record (e), Beginning of Rudder Autopilot Settings

Records (e) to (e5) are optional.

"begin rudderAutopilotSettings" (2 character strings)

"begin rudderAutopilotSettings"	Record tag.
Note:	Records (e) to (e5) are optional and can be used to supersede autopilot settings for a ship defined by SM3DBuildShip given in the file of Record (c). Within Records (e) to (e5), Records (e1) to (e4) can be repeated an arbitrary number of times to set rudder autopilot parameters as required.

Record (e1), Rudder Index for Autopilot Settings

This Record must follow Record (e) if autopilot settings are being given as input.

"indexRudderAutopilot" indexRudderAutopilot (1 character string, 1 integer)

"indexRudderAutopilot"	Record tag.
indexRudderAutopilot	Index of rudder for which autopilot settings are being specified. Rudder indices range from 0 to nRudder-1, where nRudder is the number of ship rudders. If this rudder to set to -1, then the input autopilot settings are applied to all rudders.

Record (e2), Rudder Autopilot Parameters

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"autopilotParam", deflectMaxDeg, velMaxDeg, accMaxDeg, freqResponse, dampResponse, dtMax (1 character string, 6 floats)

"autopilotControlParam"	Record tag.
deflectMaxDeg	Maximum rudder deflection angle (deg). This value is typically set to 35°. This parameter doesn't affect frequency domain computations with SM3DSeakeepRegular.
velMaxDeg	Maximum rudder deflection velocity (deg/s). If this value is set to 0.0, then the maximum velocity is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepRegular.
accMaxDeg	Maximum rudder acceleration (deg/s^2). If this value is set to 0.0, then the maximum acceleration is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepRegular.
freqResponse	Undamped response frequency of rudder autopilot.
dampResponse	Damping of rudder autopilot as a fraction of critical damping. This value is typically between 0.5 and 1.0.
dtMax	Maximum time increment for time stepping of rudder motions. This parameter doesn't affect frequency domain computations with SM3DSeakeepRegular.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e3), Rudder Autopilot Displacement Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"dispGains", surgeGain, swayGain, heaveGain, rollGain, pitchGain, yawGain (1 character string, 6 floats)

"dispGains"	Record tag.
surgeGain	Surge gain (deg/m). This value is typically 0.0.
swayGain	Sway gain (deg/m). This value is typically 0.0.
heaveGain	Heave gain (deg/m). This value is typically 0.0.
rollGain	Roll gain (deg/deg). This value is typically 0.0 unless rudder roll stabilization is desired.
pitchGain	Pitch gain (deg/deg). This value is typically 0.0.
yawGain	Yaw gain (deg/deg). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e4), Rudder Velocity Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"velGains", surgeVelGain, swayVelGain, heaveVelGain, rollVelGain, pitchVelGain, yawVelGain (1 character string, 6 floats)

"velGains"	Record tag.
surgeVelGain	Surge velocity gain (deg/(m/s)). This value is typically 0.0.
swayVelGain	Sway velocity gain (deg/(m/s)). This value is typically 0.0.
heaveVelGain	Heave velocity gain (deg/(m/s)). This value is typically 0.0.
rollVelGain	Roll velocity gain (deg/(deg/s)). This value is typically 0.0 unless rudder roll stabilization is desired.
pitchVelGain	Pitch velocity gain (deg/(deg/s)). This value is typically 0.0.
yawVelGain	Yaw velocity gain (deg/(deg/s)). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e5), End of Rudder Autopilot Settings

"end rudderAutopilotSettings" (2 character strings)

"end rudderAutopilotSettings" Record tag.

Record (f), Output Options

"outOptions", outRudderRaoOption, outRollDampOption (3 character strings)

"outOptions"	Record tag.
outRudderRaoOption	Option for writing roll damping values: outRudderRao - Rudder motions are written to output. noOutRudderRao - Rudder motions are not written to output.
outRollDampOption	Option for writing roll damping values: outRollDamp - Roll damping coefficients are written to output. noOutRollDamp - Roll damping coefficients are not written to output.

Record (g), Option for Output of Response Amplitude Operator File for Post-Processing

"outRaoPprOption", outRaoPprOption (2 character strings)

"outRaoPprOption"	Record tag.
outRaoPprOption	Option for output of data file in Python pickle file format with motion response amplitude operators for post-processing. outRaoPpr - Motion RAOs are written to a file in Python pickle format. noOutRaoPpr - Motion RAOs are not written to a file in Python pickle format.

Record (h), Output Response Amplitude Operator File Name

This record should only be given if outRaoPprOption in Record (g) is set to outRaoPpr.

"outRaoFileName", outRaoFileName (2 character strings)

"outRaoFileName"	Record tag.
outRaoFileName	Name of output file for response amplitude operators in Python pickle format.

Record (i), Minimum Wave Encounter Frequency

"enFreqMinMotion", enFreqMinMotion (1 character string, 1 float)

"enFreqMinMotion"	Record tag.
enFreqMinMotion	Minimum wave encounter frequency for ship motion predictions. If the combination of ship speed, heading, and wave frequency gives an encounter frequency less than this value, then the wave frequency is shifted. This variable is used to avoid large amplitude motions at very low encounter frequencies.

Record (j1), Ship Speed Range in m/s

One of Records (j1) to (j6) must be given.

"speedRange", speedMin, speedMax, speedInc (1 character string, 3 floats)

"speedRange"	Record tag.
speedMin	Minimum ship speed (m/s).
speedMax	Maximum ship speed (m/s).
speedInc	Increment for ship speed (m/s).

Record (j2), Ship Speeds in m/s

One of Records (j1) to (j6) must be given.

"speeds", speeds (1 character string, array of floats)

"speeds"	Record tag.
speeds	Array of ship speeds (m/s).

Record (j3), Ship Speed Range in Knots

One of Records (j1) to (j6) must be given.

"speedKnotsRange", speedKnotsMin, speedKnotsMax, speedKnotsInc (1 character string, 3 floats)

"speedKnotsRange"	Record tag.
speedKnotsMin	Minimum ship speed (knots).
speedKnotsMax	Maximum ship speed (knots).
speedKnotsInc	Increment for ship speed (knots).

Record (j4), Ship Speeds in Knots

One of Records (j1) to (j6) must be given.

"speedsKnots", speedsKnots (1 character string, array of floats)

"speedsKnots"	Record tag.
speedsKnots	Array of ship speeds (knots).

Record (j5), Froude Number Range

One of Records (j1) to (j6) must be given.

"froudeRange", froudeMin, froudeMax, froudeInc (1 character string, 3 floats)

"froudeRange"	Record tag.
froudeMin	Minimum Froude number.
froudeMax	Maximum Froude number.
froudeInc	Froude number increment.

Record (j6), Ship Froude Numbers

One of Records (j1) to (j6) must be given.

"froudes", froudes (1 character string, array of floats)

"froudes"	Record tag.
froudes	Array of ship Froude numbers.

Record (k1), Range of Sea Directions Relative to the Ship

One of Records (k1) or (k2) must be given.

"seaDirDegRange", seaDirDegMin, seaDirDegMax, seaDirDegInc (1 character string, 3 floats)

"seaDirDegRange"	Record tag.
seaDirDegMin	Minimum sea direction relative to ship (deg).
seaDirDegMax	Maximum sea direction relative to ship (deg).
seaDirDegInc	Increment sea direction relative to ship (deg).

Record (k2), Sea Directions Relative to the Ship

One of Records (k1) or (k2) must be given.

"seaDirsDeg", seaDirsDeg (1 character string, array of floats)

"seaDirsDeg"	Record tag.
seaDirsDeg	Array of sea directions relative to the ship (deg) .

Record (l1), Range of Incident Wave Frequencies

One of Records (l1) or (l2) must be given.

"waveFreqRange", waveFreqMin, waveFreqMax, waveFreqInc (1 character string, 3 floats)

"waveFreqRange"	Record tag.
waveFreqMin	Minimum incident wave frequency (rad/s).
waveFreqMax	Maximum incident wave frequency (rad/s).
waveFreqInc	Increment for incident wave frequency (rad/s).

Record (l2), Incident Wave Frequencies

One of Records (l1) or (l2) must be given.

"waveFreqs", waveFreqs (1 character string, array of floats)

"waveFreqs"	Record tag.
waveFreqs	Array of increasing incident wave frequencies (rad/s).

Record (m), Input Wave Amplitude Option

"waveAmpOption", waveAmpOption (2 character strings)

"waveAmpOption"	Record tag.
waveAmpOption	Option for input wave amplitudes as a function of wave frequency: constantAmplitude - All waves have the same amplitude a. constantSteepness - All waves have the same steepness H/λ. variableAmplitude - Wave amplitude a varies with frequency.

Record (m1), Wave Amplitude

This Record must be given if waveAmpOption is set to constantAmplitude in Record (m).

"waveAmp", waveAmp (1 character string, 1 float)

"waveAmp"	Record tag.
waveAmp	Wave amplitude at all wave frequencies (m).

Record (m2), Wave Steepness

This Record must be given if waveAmpOption is set to constantSteepness in Record (m).

"waveSteepness", waveSteepness (1 character string, 1 float)

"waveSteepness"	Record tag.
waveSteepness	Wave steepness H/λ at all wave frequencies. The wave slope ka is related to the wave steepness as follows:

$$k\,a \;=\; \pi\,H/\lambda \tag{A.1}$$

Record (m3), Wave Amplitudes

This record must be given if waveAmpOption is set to variableAmplitude in Record (m).

"waveAmps", waveAmps (1 character string, array of floats)

"waveAmps"	Record tag.
waveAmps	Wave amplitudes for wave frequencies. The number of wave amplitudes must correspond to the number of wave frequencies given by Record (l1) or Record (l2).

Record (n), Beginning of Seakeeping Position Data

This record is optional.

"begin seakeepPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (n1) to (n3) giving seakeeping position parameters. Record (o) must follow at the end of seakeeping position data.

Record (n1), Seakeeping Position Label

This record is required if a seakeeping position is being specified.

"labelPos", labelPos (2 character strings)

"labelPos"	Record tag.
labelPos	Label for seakeeping position. This can include spaces.

Record (n2), Seakeeping Position Location

This record is required if a seakeeping position is being specified.

"locationPos", stationPos, yPos, zBlPos (1 character string, 3 floats)

"locationPos"	Record tag.
stationPos	Station for seakeeping position. Station 0 is at the fore perpendicular.
yPos	Lateral coordinate (+ port) relative to ship centreline (m).
zBlPos	Vertical coordinate (+ up) relative to ship baseline (m).

Record (n3), Option for Including Radiation and Diffraction in Relative Vertical Motion

This record is optional if a seakeeping position is being specified.

"relMoRadDifOption", relMoRadDifOption (2 character strings)

"relMoRadDifOption"	Record tag.
relMoRadDifOption	Option for including radiation and diffraction in relative vertical motion: noRadDif - Wave radiation and diffraction are not considered when evaluating relative wave motion (default). nearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the seakeeping position location specified in Record (n2). wlNearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the waterline plane location specified by the longitudinal and lateral coordinates in Record (n2). direct - Wave radiation and diffraction are evaluated directly at the seakeeping position location specified in Record (n2). If the seakeeping position is above the calm waterline, then the vertical position for wave elevation is evaluated at the calm waterline. wlDirect - Wave radiation and diffraction are evaluated directly at the waterline plane location specified by the longitudinal and lateral coordinates in Record (n2).
Note:	If radiation and diffraction computations are to be included in relative motion computations (relMoRadDifOption set to nearestPanel, wlNearestPanel, direct, or wlDirect), then the ship database specified in Record (c) must have a hull radiation and diffraction database that includes velocity potentials and source strengths.

Record (o), End of Seakeeping Position Data

This record is required if Record (n) is present

"end seakeepPositions" (1 character string with 2 words)

Record (p), Beginning of Wave Kinematics Position Data

This record is optional.

"begin waveKinPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (p1) to (p3) giving wave kinematics position parameters. Record (q) must follow at the end of seakeeping position data.

Record (p1), Wave Kinematics Position Label

This record is required if a wave kinematic position is being specified.

(2 character strings)

"labelWaveKin"	Record tag.
labelWaveKin	Label for wave kinematic position. This can include spaces.

Record (p2a), Wave Kinematics Position Station and Elevation Relative to Baseline

One of Record (p2a), (p2b), or (p2c) is required if a wave kinematics position is being specified.

(1 character string, 3 floats)

"stationYZBlWaveKin"	Record tag.
stationWaveKin	Station for wave kinematic position. Station 0 is at the fore perpendicular.
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zBlWaveKin	Vertical coordinate (+ up) relative to ship baseline (m). If this position is above the calm waterline for the trimmed ship, then it is moved to the calm waterline.

Record (p2b), Wave Kinematics Position Station and Elevation Relative to Calm Waterline

One of Record (p2a), (p2b), or (p2c) is required if a wave kinematics position is being specified.

(1 character string, 3 floats)

"stationYZWlWaveKin"	Record tag.
stationWaveKin	Station for wave kinematic position. Station 0 is at the fore perpendicular.
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zWlWaveKin	Vertical coordinate (+ up) relative to the calm waterline (m).

Record (p2c), Wave Kinematics Position X Coordinate and Elevation Relative to Calm Waterline

One of Record (p2a), (p2b), or (p2c) is required if a wave kinematics position is being specified.

(1 character string, 3 floats)

"xYZWlWaveKin"	Record tag.
xWaveKin	x coordinate (+ forward, relative to ship CG) for wave kinematic position (m).
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zWlWaveKin	Vertical coordinate (+ up) relative to the calm waterline (m).

Record (p3), Option for Including Radiation and Diffraction in Wave Kinematics

This record is optional if a wave kinematics position is being specified.

(2 character strings)

"waveKinRadDif"	Record tag.
waveKinRadDifOption	Option for including radiation and diffraction in wave kinematics: noRadDif - Wave radiation and diffraction are not considered when evaluating wave kinematics (default). nearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the wave kinematics position location specified in Record (p2a), (p2b), or (p2c). direct - Wave radiation and diffraction are evaluated directly at the wave kinematics position location specified in Record (p2a), (p2b), or (p2c).
Note:	If radiation and diffraction computations are to be included in wave kinematics computations (waveKinRadDifOption set to nearestPanel or direct), then the ship database specified in Record (c) must have a hull radiation and diffraction database that includes velocity potentials and source strengths.

Record (q), End of Wave Kinematics Position Data

This record is required if Record (p) is present

"end waveKinPositions" (1 character string with 2 words)

Record (r), End Record

"end SM3DSeakeepRegular"(1 character string with 2 words)

A.2 Sample Input File for SM3DSeakeepRegular

```
begin SM3DSeakeepRegular
label Generic frigate
steadyShipDBFDFileName genFrigFDShip.pkl
loadCondition 1025.0 4.2 0.0 6.0 0.0
outOptions outRudderRao outRollDamp
outRaoPprOption noOutRaoPpr
enFreqMinMotion 0.1
speedKnotsRange 20.0 20.0 10.0
seaDirDegRange 120.0 120.0 30.0
waveFreqRange 0.2 2.0 0.1
waveAmpOption constantSteepness
waveSteepness 0.02
begin seakeepPositions
    labelPos Bridge
    locationPos 3.0 2.0 12.0
    relMoRadDifOption noRadDif
end seakeepPositions
end SM3DSeakeepRegular
```

A.3 Sample Output File for SM3DSeakeepRegular

```
Program SM3DSeakeepRegular
ShipMo3D library Version 1.0c - 26 November 2007
Time : Wed Feb 06 15:42:00 2008
Run label:
Generic frigate

**** ECHO OF USER INPUT ****

Input ship database for frequency domain computation file name:
genFrigFDShip.pkl

Ship Loading Condition
Water density : 1025.000 kg/m3
Draft of baseline at midships       :     4.200 m
Trim of baseline by stern           :     0.000 m
Height of CG above baseline, KG     :     6.000 m
Correction to metacentric height GM :     0.000 m

Output rudder motion option : outRudderRao
Output roll damping option : outRollDamp

Minimum wave encounter frequency for predicting ship motions : 0.100 rad/s

Speed range
Minimum   :   20.000 knots
Maximum   :   20.000 knots
Increment :   10.000 knots

Sea direction range
Minimum   :  120.000 deg
Maximum   :  120.000 deg
Increment :   30.000 deg

Incident wave frequency range
Minimum   :    0.200 rad/s
Maximum   :    2.000 rad/s
Increment :    0.100 rad/s

Input wave amplitude option : constantSteepness
Wave steepness for all frequencies : 0.020

Incident wave conditions
Frequency      Amplitude   Steepness     Slope
 (rad/s)         (m)
    0.200       15.403     0.020000     0.062832
    0.300        6.846     0.020000     0.062832
    0.400        3.851     0.020000     0.062832
    0.500        2.465     0.020000     0.062832
    0.600        1.711     0.020000     0.062832
    0.700        1.257     0.020000     0.062832
    0.800        0.963     0.020000     0.062832
    0.900        0.761     0.020000     0.062832
    1.000        0.616     0.020000     0.062832
    1.100        0.509     0.020000     0.062832
    1.200        0.428     0.020000     0.062832
    1.300        0.365     0.020000     0.062832
    1.400        0.314     0.020000     0.062832
    1.500        0.274     0.020000     0.062832
    1.600        0.241     0.020000     0.062832
    1.700        0.213     0.020000     0.062832
    1.800        0.190     0.020000     0.062832
    1.900        0.171     0.020000     0.062832
```

```
    2.000        0.154     0.020000     0.062832

Seakeeping Positions

Label               : Bridge
Station             :     3.000
Lateral offset y    :     2.000 m (+ port)
Vertical offset zBl :    12.000 m (+ up, relative to baseline)
Option for including radiation and diffraction for relative motion (input) : noRadDif

**** SHIP LOADING CONDITION ****

Generic frigate
Load Condition Properties for Trimmed Ship

Summary of hydrostatic properties
Number of panels on port side        :          624
Length between perpendiculars        :      120.000 m
Draft of baseline at midships        :        4.200 m
Trim of baseline by stern            :        0.000 m
Beam based on maximum y value        :       14.115 m
Volume                               :     3625.687 m3
Water density                        :     1025.000 kg/m3
Mass                                 : 3716329.367494 kg
LCB of aft of FP (m)                 :       61.739 m
X origin aft of FP (m)               :       61.739 m
X value of LCB                       :        0.000 m
Center of buoyancy wrt waterline     :       -1.620 m
Wetted surface area                  :     1754.193 m2
Waterplane area                      :     1344.547 m2
X value of center of floatation      :       -5.016 m
Integral of waterplane area*X**2     :  1235150.552 m4
Integral of waterplane area*Y**2     :    17543.034 m4
KG, height of CG above baseline      :        6.000 m
Height of CG above waterline         :        1.800 m
Metacentric height from hydrostatics :        1.418 m

Inertial Properties

Inertia matrix, units of kg, kg*m, and kg*m2
   3716329.4          0.0          0.0          0.0          0.0          0.0
         0.0    3716329.4          0.0          0.0          0.0          0.0
         0.0          0.0    3716329.4          0.0          0.0          0.0
         0.0          0.0          0.0   85624228.6          0.0          0.0
         0.0          0.0          0.0          0.0 3344696430.7          0.0
         0.0          0.0          0.0          0.0          0.0 3344696430.7

Roll radius of gyration  :     4.800 m
Pitch radius of gyration :    30.000 m
Yaw radius of gyration   :    30.000 m

Roll Metacentric Height Properities

Correction to roll metacentric height :     0.000 m
Corrected metacentric height          :     1.418 m


Roll Properties at Zero Forward Speed

Roll added mass                        : 19312942.233901 kg*m**2
Nondimensional roll added mass A44/I44 :     0.226
Natural roll frequency                 :     0.702 rad/s
Natural roll period                    :     8.953 s
```

```
**** SHIP AUTOPILOT SETTINGS ****

Generic frigate
Autopilots for Ship

Autopilot index : 0
Autopilot for ship with nominally steady speed and heading
Label: Rudder
Maximum deflection   : 35.000 deg
Maximum velocity     : 3.000 deg/s
Maximum acceleration : Not set
Response frequency   : 3.000 rad/s
Response damping     : 0.850 rad/s (fraction of critical)
Maximum time step for computing deflections : 0.100

Autopilot gains
Diplacement gains have units of deg/m and deg/deg
Velocity gains have units of deg/(m/s) and deg/(deg/s)
Yaw gains given relative to earth-fixed axes (+yaw is clockwise)
                       Surge    Sway     Heave    Roll     Pitch    Yaw
Displacement gains :    0.000    0.000    0.000    0.000    0.000   -4.000
Velocity gains     :    0.000    0.000    0.000    0.000    0.000   -8.000

**** SEAKEEPING POSITION TRIM CONDITIONS ****

Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m


**** Motions in Regular Waves ****

Speed         :    10.300 m/s (20.000 knots)
Froude number :     0.300
Sea direction :   120.000 deg (from, 180 deg head seas, 90 deg waves from port)
Surge, sway, and heave non-dimensionalized by wave amplitude
Roll, pitch, and yaw non-dimensionalized by wave slope ka

Wave freq   Enc freq    Surge       Sway        Heave       Roll        Pitch       Yaw
(rad/s)     (rad/s)     Amp Phase   Amp Phase   Amp Phase   Amp Phase   Amp Phase   Amp Phase
    0.200      0.221    0.409  95   0.789  86   1.001 360   1.141 127   0.497 269   0.444 158
    0.300      0.347    0.373  93   0.723  88   1.000 360   1.100 109   0.505 268   0.295 169
    0.400      0.484    0.343  90   0.659  90   0.993   0   1.316  82   0.527 266   0.230 177
    0.500      0.631    0.304  84   0.629  93   0.998   2   1.769   7   0.550 259   0.222 196
    0.600      0.789    0.240  78   0.541  90   1.043   2   1.014 282   0.536 251   0.227 185
    0.700      0.957    0.177  72   0.419  91   1.090 358   0.632 241   0.508 241   0.172 183
    0.800      1.136    0.110  62   0.301  95   1.135 347   0.455 220   0.463 227   0.125 186
    0.900      1.325    0.049  46   0.193 103   0.968 320   0.328 207   0.373 205   0.086 193
    1.000      1.525    0.003 298   0.106 118   0.404 287   0.215 196   0.206 175   0.055 205
    1.100      1.735    0.012 207   0.052 150   0.074 333   0.118 182   0.058 156   0.032 223
    1.200      1.956    0.009 247   0.029 203   0.097  22   0.048 151   0.013 239   0.018 252
    1.300      2.188    0.010 291   0.021 262   0.055  32   0.030  74   0.015 271   0.011 289
    1.400      2.429    0.009 302   0.021 318   0.023  67   0.036  41   0.008 275   0.007 329
    1.500      2.682    0.003 315   0.019   0   0.012 125   0.027  32   0.002 327   0.004  21
    1.600      2.944    0.003  90   0.015  34   0.010 161   0.010  33   0.003  27   0.003  80
    1.700      3.218    0.004 105   0.008  97   0.005 242   0.004 181   0.001  15   0.003 120
    1.800      3.502    0.002 121   0.007 176   0.006 264   0.008 195   0.001 214   0.001 163
    1.900      3.796    0.002 345   0.006 208   0.003 197   0.005 187   0.001 173   0.001 260
    2.000      4.101    0.003 332   0.003 262   0.008 101   0.002  98   0.001 100   0.001 321
```

**** Rudder Deflections in Regular Waves ****

Speed : 10.300 m/s (20.000 knots)
Froude number : 0.300
Sea direction : 120.000 deg (from, 180 deg head seas, 90 deg waves from port)
Rudder deflections non-dimensionalized by wave slope ka

Rudder labels for output of rudder deflections:
Rudder

Wave freq	Rudder deflections and phases	
	Amp	Phase (deg)
0.200	1.935	175
0.300	1.427	192
0.400	1.266	205
0.500	1.403	227
0.600	1.645	217
0.700	1.413	214
0.800	1.154	215
0.900	0.885	220
1.000	0.617	227
1.100	0.393	241
1.200	0.237	265
1.300	0.152	297
1.400	0.096	332
1.500	0.056	18
1.600	0.046	72
1.700	0.036	106
1.800	0.018	145
1.900	0.011	237
2.000	0.011	294

**** Roll Damping ****

Ship speed : 10.300 m/s
Relative sea direction : 120.0 deg
Speed : 10.300 m/s (20.000 knots)
Froude number : 0.300
Sea direction : 120.000 deg (from, 180 deg head seas, 90 deg waves from port)
Roll damping non-dimensionalized by critical roll damping at forward speed
Critical roll damping : 147326301.320 Nm/(rad/s)

Wave freq (rad/s)	Enc freq (rad/s)	Roll amp (deg)	Roll damping components						Added mass
			Total	Hull Radiation	Hull Viscous	Hull Maneuver	Appendage Lift	Appendage Viscous	
0.200	0.221	4.106	0.102	0.009	0.000	0.005	0.074	0.013	0.209
0.300	0.347	3.961	0.109	0.009	0.000	0.005	0.074	0.020	0.211
0.400	0.484	4.736	0.119	0.010	0.000	0.005	0.074	0.030	0.217
0.500	0.631	6.370	0.135	0.013	0.000	0.005	0.074	0.042	0.224
0.600	0.789	3.651	0.146	0.021	0.000	0.005	0.074	0.046	0.226
0.700	0.957	2.274	0.162	0.031	0.000	0.005	0.074	0.051	0.220
0.800	1.136	1.639	0.181	0.043	0.000	0.005	0.074	0.059	0.208
0.900	1.325	1.179	0.197	0.053	0.000	0.005	0.074	0.065	0.191
1.000	1.525	0.773	0.205	0.056	0.000	0.005	0.074	0.070	0.174
1.100	1.735	0.424	0.190	0.055	0.000	0.005	0.074	0.056	0.163
1.200	1.956	0.171	0.156	0.051	0.000	0.005	0.074	0.025	0.156
1.300	2.188	0.109	0.144	0.046	0.000	0.005	0.074	0.018	0.152
1.400	2.429	0.131	0.145	0.041	0.000	0.005	0.074	0.024	0.153
1.500	2.682	0.098	0.136	0.037	0.000	0.005	0.074	0.020	0.153
1.600	2.944	0.037	0.119	0.031	0.000	0.005	0.074	0.008	0.153
1.700	3.218	0.013	0.111	0.029	0.000	0.005	0.074	0.003	0.155
1.800	3.502	0.028	0.114	0.028	0.000	0.005	0.074	0.007	0.157

1.900	3.796	0.018	0.110	0.026	0.000	0.005	0.074	0.005	0.158
2.000	4.101	0.008	0.115	0.034	0.000	0.005	0.074	0.002	0.162

**** Motions at Seakeeping Positions in Regular Waves ****

Ship speed : 10.300 m/s
Relative sea direction : 120.0 deg

Label : Bridge
Station : 3.000
y : 2.000 m
zBl : 12.000 m
All displacements non-dimensionalized by wave amplitude

Wave frequency	Encounter frequency	Longitudinal displacement		Lateral displacement		Vertical displacement		Rel vertical displacement	
		Amp	Phase (deg)	Amp	Phase (deg)	Amp	Phase (deg)	Amp	Phase (deg)
0.200	0.221	0.396	95	0.794	90	1.001	5	0.002	337
0.300	0.347	0.344	92	0.692	96	1.024	12	0.024	14
0.400	0.484	0.291	90	0.571	109	1.110	22	0.110	26
0.500	0.631	0.225	83	0.755	136	1.365	28	0.385	13
0.600	0.789	0.128	77	0.833	119	1.550	30	0.697	1
0.700	0.957	0.035	90	0.637	117	1.824	29	1.213	358
0.800	1.136	0.065	211	0.448	123	2.073	19	1.959	350
0.900	1.325	0.126	198	0.275	137	1.917	358	2.498	336
1.000	1.525	0.115	173	0.149	169	1.104	334	2.084	326
1.100	1.735	0.048	159	0.124	227	0.364	333	1.356	343
1.200	1.956	0.015	239	0.146	260	0.166	43	1.152	22
1.300	2.188	0.022	277	0.132	277	0.162	73	1.154	56
1.400	2.429	0.016	281	0.080	295	0.100	82	1.099	90
1.500	2.682	0.006	305	0.025	348	0.034	120	1.034	130
1.600	2.944	0.005	42	0.036	82	0.035	194	1.032	174
1.700	3.218	0.004	53	0.038	106	0.024	202	1.023	218
1.800	3.502	0.001	168	0.014	136	0.004	351	1.000	267
1.900	3.796	0.002	160	0.014	284	0.017	346	1.015	318
2.000	4.101	0.003	66	0.021	305	0.016	280	1.000	11

Annex B: Files for Motions in a Random Seaway with SM3DSeakeepRandom

B.1 Format of Input File for SM3DSeakeepRandom

Record (a), Beginning Record

"begin SM3DSeakeepRandom"(1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for run. This can include spaces.

Record (c), Input Ship Database File Name

"steadyShipDBFDFileName", steadyShipDBFDFileName (2 character strings)

"steadyShipDBFDFileName"	Record tag.
steadyShipDBFDFileName	Name of input ship database file in Python pickle format. This file must have been created using program SM3DBuildShip.

Record (d), Ship Loading Condition

"loadCondition", waterDensity, draftBlMid, trimBlStern, shipKG, correctionGM (1 character string, 5 floats)

"loadCondition"	Record tag.
waterDensity	Water density (kg/m^3).
draftBlMid	Draft of baseline at midships (m).
trimBlStern	Trim of baseline by stern (m).
shipKG	Height of centre of gravity above baseline (m).
correctionGM	Correction to metacentric height (m).
Note:	The values in this record must agree with the values used for the ship database file specified in Record (c) Values are considered to be in agreement when they are within a tolerance of 0.001 kg/m^3 for density, and 0.001 m for draft, trim, height of CG, and metacentric height. The output file from SM3DBuildShip gives the values of the above parameters.

Record (e), Beginning of Rudder Autopilot Settings

Records (e) to (e5) are optional.

"begin rudderAutopilotSettings" (2 character strings)

"begin rudderAutopilotSettings"	Record tag.
Note:	Records (e) to (e5) are optional and can be used to supersede autopilot settings for a ship defined by SM3DBuildShip given in the file of (c). Within Records (e) to (e5), Records (e1) to (e4) can be repeated an arbitrary number of times to set rudder autopilot parameters as required.

Record (e1), Rudder Index for Autopilot Settings

This Record must follow Record (e) if autopilot settings are being given as input.

"indexRudderAutopilot" indexRudderAutopilot (1 character string, 1 integer)

"indexRudderAutopilot"	Record tag.
indexRudderAutopilot	Index of rudder for which autopilot settings are being specified. Rudder indices range from 0 to nRudder−1, where nRudder is the number of ship rudders. If this rudder to set to −1, then the input autopilot settings are applied to all rudders.

Record (e2), Rudder Autopilot Parameters

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"autoPilotParam", deflectMaxDeg, velMaxDeg, accMaxDeg, freqResponse, dampResponse, dtMax (1 character string, 6 floats)

"autoPilotControlParam"	Record tag.
deflectMaxDeg	Maximum rudder deflection angle (deg). This value is typically set to 35°. This parameter doesn't affect frequency domain computations with SM3DSeakeepRandom.
velMaxDeg	Maximum rudder deflection velocity (deg/s). If this value is set to 0.0, then the maximum velocity is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepRandom.
accMaxDeg	Maximum rudder acceleration (deg/s^2). If this value is set to 0.0, then the maximum acceleration is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepRandom.
freqResponse	Undamped response frequency of rudder autopilot.
dampResponse	Damping of rudder autopilot as a fraction of critical damping. This value is typically between 0.5 and 1.0.
dtMax	Maximum time increment for time stepping of rudder motions. This parameter doesn't affect frequency domain computations with SM3DSeakeepRandom.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e3), Rudder Autopilot Displacement Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"dispGains", surgeGain, swayGain, heaveGain, rollGain, pitchGain, yawGain (1 character string, 6 floats)

"dispGains"	Record tag.
surgeGain	Surge gain (deg/m). This value is typically 0.0.
swayGain	Sway gain (deg/m). This value is typically 0.0.
heaveGain	Heave gain (deg/m). This value is typically 0.0.
rollGain	Roll gain (deg/deg). This value is typically 0.0 unless rudder roll stabilization is desired.
pitchGain	Pitch gain (deg/deg). This value is typically 0.0.
yawGain	Yaw gain (deg/deg). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e4), Rudder Velocity Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"velGains", surgeVelGain, swayVelGain, heaveVelGain, rollVelGain, pitchVelGain, yawVelGain (1 character string, 6 floats)

"velGains"	Record tag
surgeVelGain	Surge velocity gain (deg/(m/s)). This value is typically 0.0.
swayVelGain	Sway velocity gain (deg/(m/s)). This value is typically 0.0.
heaveVelGain	Heave velocity gain (deg/(m/s)). This value is typically 0.0.
rollVelGain	Roll velocity gain (deg/(deg/s)). This value is typically 0.0 unless rudder roll stabilization is desired.
pitchVelGain	Pitch velocity gain (deg/(deg/s)). This value is typically 0.0.
yawVelGain	Yaw velocity gain (deg/(deg/s)). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e5), End of Rudder Autopilot Settings

"end rudderAutopilotSettings" (2 character strings)

"end rudderAutopilotSettings"	Record tag.

Record (f), Output Options for Parameters in Regular Seas

"outRaoOptions", outRaoOptions (2 character strings)

"outRaoOptions"	Record tag.
outMotionRaoOption	Option for writing motion RAOs: outMotionRao - Ship motion RAOs are written to output. noOutMotionRao - Ship motion RAOs are not written to output.
outRudderRaoOption	Option for writing rudder deflection RAOs: outRudderRao - Rudder deflection RAOs are written to output. noOutRudderRao - Rudder deflection RAOs are not are written to output.
outRollDampOption	Option for writing roll damping values: outRollDamp - Roll damping coefficients are written to output. noOutRollDamp - Roll damping coefficients are not written to output.
outPositionRaoOption	Option for writing seakeeping position RAOs: outPositionRao - Seakeeping positions RAOs are written to output. noOutPositionRao - Seakeeping positions RAOs are not written to output.
outWaveKinRaoOption	Option for writing wave kinematics RAOs: outWaveKinRao - Wave kinematics RAOs are written to output. noOutWaveKinRao - Wave kinematics RAOs are not written to output.

Record (g), Option for Output of Response Amplitude Operator File for Post-Processing

"outRaoPprOption", outRaoPprOption (2 character strings)

"outRaoPprOption"	Record tag.
outRaoPprOption	Option for output of data file in Python pickle file format with motion response amplitude operators for post-processing. outRaoPpr - Motion RAOs are written to a file in Python pickle format. noOutRaoPpr - Motion RAOs are not written to a file in Python pickle format.

Record (h), Output Response Amplitude Operator File Name

This record should only be given if outRaoPprOption in Record (g) is set to outRaoPpr.

"outRaoPprFileName", outRaoPprFileName (2 character strings)

"outRaoPprFileName"	Record tag.
outRaoPprFileName	Name of output file for RAOs in Python pickle format.

Record (i), Minimum Wave Encounter Frequency

"enFreqMinMotion", enFreqMinMotion (1 character string, 1 float)

"enFreqMinMotion"	Record tag.
enFreqMinMotion	Minimum wave encounter frequency for ship motion predictions. If the combination of ship speed, heading, and wave frequency gives an encounter frequency less than this value, then the wave frequency is shifted. This variable is used to avoid large amplitude motions at very low encounter frequencies.

Record (j1), Ship Speed Range in m/s

One of Records (j1) to (j6) must be given.

"speedRange", speedMin, speedMax, speedInc (1 character string, 3 floats)

"speedRange"	Record tag.
speedMin	Minimum ship speed (m/s).
speedMax	Maximum ship speed (m/s).
speedInc	Increment for ship speed (m/s).

Record (j2), Ship Speeds in m/s

One of Records (j1) to (j6) must be given.

"speeds", speeds (1 character string, array of floats)

"speeds"	Record tag.
speeds	Array of ship speeds (m/s).

Record (j3), Ship Speed Range in Knots

One of Records (j1) to (j6) must be given.

"speedKnotsRange", speedKnotsMin, speedKnotsMax, speedKnotsInc (1 character string, 3 floats)

"speedKnotsRange"	Record tag.
speedKnotsMin	Minimum ship speed (knots).
speedKnotsMax	Maximum ship speed (knots).
speedKnotsInc	Increment for ship speed (knots).

Record (j4), Ship Speeds in Knots

One of Records (j1) to (j6) must be given.

"speedsKnots", speedsKnots (1 character string, array of floats)

"speedsKnots"	Record tag.
speedsKnots	Array of ship speeds (knots).

Record (j5), Froude Number Range

One of Records (j1) to (j6) must be given.

"froudeRange", froudeMin, froudeMax, froudeInc (1 character string, 3 floats)

"froudeRange"	Record tag.
froudeMin	Minimum Froude number.
froudeMax	Maximum Froude number.
froudeInc	Froude number increment.

Record (j6), Ship Froude Numbers

One of Records (j1) to (j6) must be given.

"froudes", froudes (1 character string, array of floats)

"froudes"	Record tag.
froudes	Array of ship Froude numbers.

Record (k1), Range of Sea Directions Relative to the Ship for Computing Motion RAOs

One of Records (k1) or (k2) must be given.

"seaDirDegRange", seaDirDegMin, seaDirDegMax, seaDirDegInc (1 character string, 3 floats)

"seaDirDegRange"	Record tag.
seaDirDegMin	Minimum sea direction relative to ship (deg).
seaDirDegMax	Maximum sea direction relative to ship (deg).
seaDirDegInc	Increment sea direction relative to ship (deg).

Record (k2), Sea Directions Relative to the Ship for Computing Motion RAOs

One of Records (k1) or (k2) must be given.

"seaDirsDeg", seaDirsDeg (1 character string, array of floats)

"seaDirsDeg"	Record tag.
seaDirsDeg	Array of sea directions relative to the ship (deg) .

Record (l1), Range of Sea Directions Relative to the Ship for Seakeeping Computations in Random Seas

One of Records (l1) or (l2) can optionally be given.

"seaDirDegRangeSeakeep", seaDirDegSeakeepMin, seaDirDegSeakeepMax, seaDirDegSeakeepInc (1 character string, 3 floats)

"seaDirDegRangeSeakeep"	Record tag.
seaDirDegSeakeepMin	Minimum sea direction relative to ship for seakeeping computations (deg).
seaDirDegSeakeepMax	Maximum sea direction relative to ship for seakeeping computations (deg).
seaDirDegSeakeepInc	Increment sea direction relative to ship for seakeeping computations (deg).
Note:	Either Record (l1) or (l2) can optionally be given as input to specify sea directions for seakeeping computations. If neither record is given, then seakeeping computations are performed for sea directions specified by either Record (k1) or Record (k2).

Record (l2), Sea Directions Relative to the Ship for Seakeeping Computations in Random Seas

One of Records (l1) or (l2) can optionally be given.

"seaDirsDegSeakeep", seaDirsDegSeakeep (1 character string, array of floats)

"seaDirsDegSeakeep"	Record tag.
seaDirsDegSeakeep	Array of sea directions relative to the ship for seakeeping computations (deg) .
Note:	Either Record (l1) or (l2) can optionally be given as input to specify sea directions for seakeeping computations. If neither record is given, then seakeeping computations are performed for sea directions specified by either Record (k1) or Record (k2).

Record (m1), Range of Incident Wave Frequencies

One of Records (m1) or (m2) must be given.

"waveFreqRange", waveFreqMin, waveFreqMax, waveFreqInc (1 character string, 3 floats)

"waveFreqRange"	Record tag.
waveFreqMin	Minimum incident wave frequency (rad/s).
waveFreqMax	Maximum incident wave frequency (rad/s).
waveFreqInc	Increment for incident wave frequency (rad/s).

Record (m2), Incident Wave Frequencies

One of Records (m1) or (m2) must be given.

"waveFreqs", waveFreqs (1 character string, array of floats)

"waveFreqs"	Record tag.
waveFreqs	Array of increasing incident wave frequencies (rad/s).

Record (n), Wave Spectrum Type

"spectrumType", spectrumType (2 character strings)

"spectrumType"	Record tag.
spectrumType	Wave spectrum type. Options are: Bretschneider - Bretschneider spectrum. JONSWAP - JONSWAP spectrum. OchiHubble - Six parameter Ochi and Hubble spectrum. inputSpectrum - Input spectral densities.

Record (o1), Parameters for Bretschneider Spectrum

This record is required if spectrumType is set to Bretschneider in Record (n).

"BretParam", hs, tp (1 character string, 2 floats)

"BretParam"	Record tag.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).

Record (o2), Parameters for JONSWAP Spectrum

This record is required if spectrumType is set to JONSWAP in Record (n).

"JONSWAPParam", waveHeadingDeg, hs, tp, peakEnhance (1 character string, 3 floats)

"JONSWAPParam"	Record tag.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).
peakEnhance	Peak enhancement factor γ. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.

Record (o3), Parameters for Ochi and Hubble Six Parameter Spectrum

This record is required if spectrumType is set to OchiHubble in Record (n).

"OchiHubbleParam", hs1, freqPeak1, spectralShape1, hs2, freqPeak2, spectralShape2 (1 character string, 6 floats)

"OchiHubbleParam"	Record tag.
hs1	Significant wave height h_{s-1} of wave system 1 (m).
freqPeak1	Peak wave frequency ω_{p-1} of wave system 1 (rad/s).
spectralShape1	Spectral shape factor λ_1 of wave system 1.
hs2	Significant wave height h_{s-2} of wave system 2 (m).
freqPeak2	Peak wave frequency ω_{p-2} of wave system 2 (rad/s).
spectralShape2	Spectral shape factor λ_2 of wave system 2.

Record (o4a), Input Spectrum Wave Frequencies

This record is required if spectrumType in Record (n) is set to inputSpectrum.

"inputWaveFreqs", inputWaveFreqs (1 character string, array of floats)

"inputWaveFreqs"	Record tag.
inputWaveFreqs	Wave frequencies ω_I for input energy densities (rad/s).

Record (o4b), Input Spectrum Energy Densities

This record is required if spectrumType in Record (n) is set to inputSpectrum.

"inputEnergyDensities", inputEnergyDensities (1 character string, array of floats)

"inputEnergyDensities"	Record tag.
inputEnergyDensities	Wave spectrum energy densities $S_{\omega_I}(\omega_I)$ corresponding to wave frequencies of Record (o4a).

Record (p), Directional Spreading Angle

"spreadAngleDeg", spreadAngleDeg (1 character string, 1 float)

"spreadAngleDeg"	Record tag.
spreadAngleDeg	Directional spreading angle θ_s (degrees). If short-crested seas are being modelled (non-zero spreading angle), then the sea directions specified by Record (k1) or (k2) must go from 0 to 180 degrees, with a maximum increment of 30 degrees between adjacent sea directions.

Record (q), Beginning of Steady Wave Data

This record is optional.

"begin steadyWaveData" (1 character string with 2 words)

Record (q1), Number of Speeds for Steady Wave Input Data

This record is required if a steady wave data are being specified.

"nSpeedStation", nSpeedSteady, nStationSteady (1 character string, 2 integers)

"nSpeedStation"	Record tag.
nSpeedSteady	Number of speeds for which steady wave data are being specified. This value must be ≥ 1.
nStationSteady	Number of stations for which steady wave profile data are being specified. If this value is 0, then no steady wave profile data are specified.

Record (q2a), Speeds in m/s for Steady Wave Data

One of Records (q2a), (q2b), or (q2c) are required if steady wave data are being given.

"speedsSteady", speedsSteady (1 character string, nSpeedSteady floats)

"speedsSteady"	Record tag.
speedsSteady	Ship speeds for steady wave data (m/s).

Record (q2b), Speeds in Knots for Steady Wave Data

One of Records (q2a), (q2b), or (q2c) are required if steady wave data are being given.

"speedsKnotsSteady", speedsKnotsSteady (1 character string, nSpeedSteady floats)

"speedsKnotsSteady"	Record tag.
speedsKnotsSteady	Ship speeds for steady wave data (knots).

Record (q2c), Froude numbers for Steady Wave Data

One of Records (q2a), (q2b), or (q2c) are required if steady wave data are being given.

"froudesSteady", froudesSteady (1 character string, nSpeedSteady floats)

"froudesSteady"	Record tag.
froudesSteady	Froude numbers for steady wave data.

Record (q3), Ship Steady Heave (Sinkage) Data

This record is required if steady wave data are being given.

"heavesSteady", heavesSteady (1 character string, nSpeedSteady floats)

"heavesSteady"	Record tag.
heavesSteady	Ship heave values (m, + up) for steady ship speeds.

Record (q4), Ship Steady Pitch (Trim) Data

This record is required if steady wave data are being given.

"pitchsSteady", pitchsSteadyDeg (1 character string, nSpeedSteady floats)

"pitchsSteady"	Record tag.
pitchsSteadyDeg	Ship pitch values (deg, + bow down) for steady ship speeds.

Record (q5), Steady Wave Elevation Profile Data

This record must be given nStationSteady times, where nStationSteady is the number of stations specified in Record (q1).

"stationWaveElevsSteady", stationSteady, waveElevsSteady (1 character string, 1 + nSpeedSteady floats)

"stationWaveElevsSteady"	Record tag.
stationSteady	Station number for input wave elevations.
waveElevsSteady	Wave elevations (m) at stationSteady for ship speeds specified in Record (q2a), (q2b), or (q2c).

Record (r), End of Steady Wave Data

This record is required if Record (r) and subsequent records have been entered.

"end steadyWaveData" (1 character string with 2 words)

Record (s), Beginning of Seakeeping Position Data

This record is optional.

"begin seakeepPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (s1) to (s7f) giving seakeeping position parameters. Record (t) must follow at the end of all seakeeping position data.

Record (s1), Seakeeping Position Label

This record is required if a seakeeping position is being specified.

(2 character strings)

"labelPos"	Record tag.
labelPos	Label for seakeeping position. This can include spaces.

Record (s2), Seakeeping Position Location

This record is required if a seakeeping position is being specified.

(1 character string, 3 floats)

"locationPos"	Record tag.
stationPos	Station for seakeeping position. Station 0 is at the fore perpendicular.
yPos	Lateral coordinate (+ port) relative to ship centreline (m).
zBlPos	Vertical coordinate (+ up) relative to ship baseline (m).

Record (s3), Option for Including Radiation and Diffraction when Evaluating Relative Vertical Motion

This record is optional if a seakeeping position is being specified.

"relMoRadDifOption" relMoRadDifOption (2 character strings)

"relMoRadDifOption"	Record tag.
relMoRadDifOption	Option for including radiation and diffraction in relative vertical motion: noRadDif - Wave radiation and diffraction are not considered when evaluating relative wave motion (default). nearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the seakeeping position location specified in Record (s2). wlNearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the waterline plane location specified by the longitudinal and lateral coordinates in Record (s2). direct - Wave radiation and diffraction are evaluated directly at the seakeeping position location specified in Record (s2). If the seakeeping position is above the calm waterline, then the vertical position for wave elevation is evaluated at the calm waterline. wlDirect - Wave radiation and diffraction are evaluated directly at the waterline plane location specified by the longitudinal and lateral coordinates in Record (s2).
Note:	If radiation and diffraction computations are to be included in relative motion computations (relMoRadDifOption set to nearestPanel, wlNearestPanel, direct, or wlDirect), then the ship database specified in Record (c) must have a hull radiation and diffraction database that includes velocity potentials and source strengths.

Record (s4), Option for Including the Steady Wave Due to Ship Forward Speed when Evaluating Wetness or Emergence Events

This record is optional if a seakeeping position is being specified.

"relMoSteadyWaveOption", relMoSteadyWaveOption (2 character strings)

"relMoSteadyWaveOption"	Record tag.
relMoSteadyWaveOption	Option for including the influence of the steady wave field due to ship forward speed when evaluating distance from the waterline in calm water: noSteadyWave - The steady wave due to ship forward speed is not included (default). This option must be used if no steady wave data are provided in Records (q) to (r). sinkageTrimOnly - The ship sinkage and trim due to ship forward speed are included when evaluated vertical position relative to the calm waterline. Sinkage and trim values specified in input Records (q3) and (q4). steadyWaveElev - The steady wave elevation is evaluated based on the input steady wave profile specified in Records (q5).

Record (s5), Option for Motion-Induced Interruptions

This record is required if a seakeeping position is being specified.

"miiOption", miiOption (2 character strings)

"miiOption"	Record tag.
miiOption	Option for motion-induced interruption computations: mii - Motion-induced interruption computations are performed. noMii - No motion-induced interruption computations are performed.

Record (s6), Parameters for Motion-Induced Interruptions

This record is required if miiOption is set to mii in Record (s5).

"miiParam", tipCoLat, tipCoLong, durationMii (1 character strings, 3 floats)

"miiParam"	Record tag.
tipCoLat	Lateral tipping coefficient. A value of 0.25 is typically used for humans facing forward.
tipCoLong	Longitudinal tipping coefficient. A value of 0.17 is typically used for humans facing forward.
durationMii	Duration for computing incidence of motion-induced interruptions (s). A value of 60 s is typically used.
Note:	For sliding calculations, the user should set tipCoLat and tipCoLong equal to the static coefficient of friction.

Record (s7), Option for Slamming, Deck Wetness, or Emergence Computations

This record is required if a seakeeping position is being specified.

"slamWetEmergeOption", slamWetEmergeOption (2 character strings)

"slamWetEmergeOption"	Record tag.
slamWetEmergeOption	Option for slamming, deck wetness, or emergence computations: noSlamWetEmerge - No slamming, deck wetness, or emergence computations are performed. slamPressureCoWidth - Slamming calculations are performed using an input slamming form factor and effective pressure width specified in Record (s7b). slamWedge - Slamming calculations are performed using wedge dimensions given in Record (s7c). slamOffsets - Slamming calculations are performed using offsets given in Records (s7d), (s7e), and (s7f). wetnessEmerge - Incidence of wetness or emergence calculations are performed, depending on whether the position is above or below the waterline.

Record (s7a), Duration and Exceedence Probability for Slamming Statistics

This record is required if slamWetEmergeOption in Record (s7) is set to slamPressureCoWidth, slamWedge, or slamOffsets.

"durationPExSlam", durationSlamHours, pExceedSlam (1 character string, 2 floats)

"durationPExSlam"	Record tag.
durationSlamHours	Duration for slamming statistics (hours).
pExceedSlam	Exceedence probability for slamming statistics.

Record (s7b), Slamming Pressure Coefficient and Effective Pressure Width

This record is required if slamWetEmergeOption in Record (s7) is set to slamPressureCoWidth.

"slamPressureCoWidth", slamPressureCo, slamForceWidth (1 character string, 2 floats)

"slamPressureCoWidth"	Record tag.
slamPressureCo	Slamming pressure coefficient.
slamForceWidth	Effective slamming force width (m).

Record (s7c), Wedge Geometry for Slamming Calculations

This record is required if slamWetEmergeOption in Record (s7) is set to slamWedge.

"slamWedge", deadRiseDeg, slamForceHeight (1 character string, 2 floats)

"slamWedge"	Record tag.
deadRiseDeg	Hull deadrise angle at keel (degrees). This value must be greater than 0 degrees. For deadrise angles less than 5 degrees, this approach can be inaccurate, and is recommended that either the slamForm or slamOffsets option be used instead for slamWetEmergeOption in Record (s7).
slamForceHeight	Height above the keel at which slamming pressure goes to zero (typically taken as $0.1T_x$).

Record (s7d), Elevation Above Baseline for Zero Slamming Pressure

This record is required if slamWetEmergeOption in Record (s7) is set to slamOffsets.

"zBlZeroSlamPres", zBlZeroSlamPres (1 character string, 1 float)

"zBlZeroSlamPres"	Record tag.
zBlZeroSlamPres	Elevation above baseline at which slamming pressure goes to zero (m). This value is typically assumed to be at a height of $0.1T_x$ above the baseline, where T_x is sectional draft.

Record (s7e), Y Offsets for Performing Slamming Calculations

This record is required if slamWetEmergeOption in Record (s7) is set to slamOffsets.

"yOffsetsSlam", yOffsetsSlam (1 character string, array of floats)

"yOffsetsSlam"	Record tag.
yOffsetsSlam	Horizontal offsets for points going from keel to at least zBlZeroSlamPres (Record (s7d)) above the baseline (m).

Record (s7f), Z Offsets for Performing Slamming Calculations

This record is required if slamWetEmergeOption in Record (s7) is set to slamOffsets.

"zBlOffsetsSlam", zBlOffsetsSlam (1 character string, array of floats)

"zBlOffsetsSlam"	Record tag.
zBlOffsetsSlam	Vertical offsets for points going from keel to at least zBlZeroSlamPres (Record (s7d)) above the baseline (m).

Record (t), End of Seakeeping Position Data

This record is required if Record (s) is present.

"end seakeepPositions" (1 character string with 2 words)

Record (u), Beginning of Wave Kinematics Position Data

This record is optional.

"begin waveKinPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (u1) to (u3) giving wave kinematics position parameters. Record (v) must follow at the end of seakeeping position data.

Record (u1), Wave Kinematics Position Label

This record is required if a wave kinematic position is being specified.

"labelWaveKin", labelWaveKin (2 character strings)

"labelWaveKin"	Record tag.
labelWaveKin	Label for wave kinematic position. This can include spaces.

Record (u2a), Wave Kinematics Position Station and Elevation Relative to Baseline

One of Record (u2a), (u2b), or (u2c) is required if a wave kinematics position is being specified.

"stationYZBlWaveKin", stationWaveKin, yWaveKin, zBlWaveKin (1 character string, 3 floats)

"stationYZBlWaveKin"	Record tag.
stationWaveKin	Station for wave kinematic position. Station 0 is at the fore perpendicular.
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zBlWaveKin	Vertical coordinate (+ up) relative to ship baseline (m). If this position is above the calm waterline for the trimmed ship, then it is moved to the calm waterline.

Record (u2b), Wave Kinematics Position Station and Elevation Relative to Calm Waterline

One of Record (u2a), (u2b), or (u2c) is required if a wave kinematics position is being specified.

"stationYZWlWaveKin", stationWaveKin, yWaveKin, zWlWaveKin (1 character string, 3 floats)

"stationYZWlWaveKin"	Record tag.
stationWaveKin	Station for wave kinematic position. Station 0 is at the fore perpendicular.
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zWlWaveKin	Vertical coordinate (+ up) relative to the calm waterline (m).

Record (u2c), Wave Kinematics Position X Coordinate and Elevation Relative to Calm Waterline

One of Record (u2a), (u2b), or (u2c) is required if a wave kinematics position is being specified.

"xYZWlWaveKin", xWaveKin, yWaveKin, zWlWaveKin (1 character string, 3 floats)

"xYZWlWaveKin"	Record tag.
xWaveKin	x coordinate (+ forward, relative to ship CG) for wave kinematic position (m).
yWaveKin	Lateral coordinate (+ port) relative to ship centreline (m).
zWlWaveKin	Vertical coordinate (+ up) relative to the calm waterline (m).

Record (u3), Option for Including Radiation and Diffraction in Wave Kinematics

This record is optional if a wave kinematics position is being specified.

"waveKinRadDif", waveKinRadDifOption (2 character strings)

"waveKinRadDif"	Record tag.
waveKinRadDifOption	Option for including radiation and diffraction in wave kinematics: noRadDif - Wave radiation and diffraction are not considered when evaluating wave kinematics (default). nearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the wave kinematics position location specified in Record (u2a), (u2b), or (u2c). direct - Wave radiation and diffraction are evaluated directly at the wave kinematics position location specified in Record (u2a), (u2b), or (u2c).
Note:	If radiation and diffraction computations are to be included in wave kinematics computations (waveKinRadDifOption set to nearestPanel or direct), then the ship database specified in Record (c) must have a hull radiation and diffraction database that includes velocity potentials and source strengths.

Record (v), End of Wave Kinematics Position Data

This record is required if Record (u) is present.

"end waveKinPositions" (1 character string with 2 words)

Record (w), End Record

"end SM3DSeakeepRandom"(1 character string with 2 words)

B.2 Sample Input File for SM3DSeakeepRandom

```
begin SM3DSeakeepRandom
label Generic frigate
steadyShipDBFDFileName genFrigFDShip.pkl
loadCondition 1025.0 4.2 0.0 6.0 0.0
outRaoOptions noOutMotionRao noOutRudderRao noOutRollDamp !
              noOutPositionRao noOutWaveKinRao
outRaoPprOption outRaoPpr
outRaoPprFileName genFrigRao.pkl
enFreqMinMotion 0.1
speedKnotsRange 20.0 20.0 10.0
seaDirDegRange 0.0 180.0 30.0
waveFreqRange 0.2 2.0 0.1
spectrumType Bretschneider
BretParam 3.25 9.7
spreadAngleDeg 0.0
begin seakeepPositions
    labelPos Bridge
    locationPos 3.0 2.0 12.0
    relMoRadDifOption noRadDif
    relMoSteadyWaveOption noSteadyWave
    miiOption mii
    miiParam 0.25 0.17 60.0
    slamWetEmergeOption wetnessEmerge
end seakeepPositions
end SM3DSeakeepRandom
```

B.3 Sample Output File for SM3DSeakeepRandom

```
Program SM3DSeakeepRandom
ShipMo3D library Version 1.0c - 26 November 2007
Time : Wed Feb 06 15:42:09 2008
Run label:
Generic frigate

**** ECHO OF USER INPUT ****

Input ship database for frequency domain computation file name:
genFrigFDShip.pkl

Ship Loading Condition
Water density : 1025.000 kg/m3
Draft of baseline at midships       :     4.200 m
Trim of baseline by stern           :     0.000 m
Height of CG above baseline, KG     :     6.000 m
Correction to metacentric height GM :     0.000 m

Options for Output of Response Amplitude Operations in Long-crested Seas
Output motion RAO option               : noOutMotionRao
Output rudder motion                   : noOutRudderRao
Output roll damping option             : noOutRollDamp
Output seakeeping position option      : noOutPositionRao
Output wave kinematics option          : noOutWaveKinRao

Output RAO post-processing file option : outRaoPpr
File name with RAOs for post-processing :  genFrigRao.pkl

Minimum wave encounter frequency for predicting ship motions : 0.100 rad/s

Speed range
Minimum   :   20.000 knots
Maximum   :   20.000 knots
Increment :   10.000 knots

Sea direction range
Minimum   :    0.000 deg
Maximum   :  180.000 deg
Increment :   30.000 deg

Incident wave frequency range
Minimum   :    0.200 rad/s
Maximum   :    2.000 rad/s
Increment :    0.100 rad/s

Seaway
Bretschneider spectrum parameters
Significant wave height :     3.250 m
Peak wave period        :     9.700 s
Wave spreading angle    :       0.0 deg

Seakeeping Positions

Label               : Bridge
Station             :     3.000
Lateral offset y    :     2.000 m (+ port)
Vertical offset zBl :    12.000 m (+ up, relative to baseline)
Option for including radiation and diffraction for relative motion (input) : noRadDif
Option for including steady wave due to ship forward speed (input) : noSteadyWave
Option for motion-induced interruption computations :  mii
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
```

```
Longitudinal tipping coefficient :     0.170
Duration for MII incidence       :      60.0 s
Option for slamming, wetness, or emergence computations :  wetnessEmerge

**** SHIP LOADING CONDITION ****

Generic frigate
Load Condition Properties for Trimmed Ship

Summary of hydrostatic properties
Number of panels on port side        :          624
Length between perpendiculars        :      120.000 m
Draft of baseline at midships        :        4.200 m
Trim of baseline by stern            :        0.000 m
Beam based on maximum y value        :       14.115 m
Volume                               :     3625.687 m3
Water density                        :     1025.000 kg/m3
Mass                                 : 3716329.367494 kg
LCB of aft of FP (m)                 :       61.739 m
X origin aft of FP (m)               :       61.739 m
X value of LCB                       :        0.000 m
Center of buoyancy wrt waterline     :       -1.620 m
Wetted surface area                  :     1754.193 m2
Waterplane area                      :     1344.547 m2
X value of center of floatation      :       -5.016 m
Integral of waterplane area*X**2     :  1235150.552 m4
Integral of waterplane area*Y**2     :    17543.034 m4
KG, height of CG above baseline      :        6.000 m
Height of CG above waterline         :        1.800 m
Metacentric height from hydrostatics :        1.418 m

Inertial Properties

Inertia matrix, units of kg, kg*m, and kg*m2
   3716329.4          0.0          0.0          0.0          0.0          0.0
         0.0    3716329.4          0.0          0.0          0.0          0.0
         0.0          0.0    3716329.4          0.0          0.0          0.0
         0.0          0.0          0.0   85624228.6          0.0          0.0
         0.0          0.0          0.0          0.0 3344696430.7          0.0
         0.0          0.0          0.0          0.0          0.0 3344696430.7

Roll radius of gyration  :     4.800 m
Pitch radius of gyration :    30.000 m
Yaw radius of gyration   :    30.000 m

Roll Metacentric Height Properities

Correction to roll metacentric height :     0.000 m
Corrected metacentric height          :     1.418 m


Roll Properties at Zero Forward Speed

Roll added mass                       : 19312942.233901 kg*m**2
Nondimensional roll added mass A44/I44 :     0.226
Natural roll frequency                :     0.702 rad/s
Natural roll period                   :     8.953 s


**** SHIP AUTOPILOT SETTINGS ****

Generic frigate
Autopilots for Ship
```

```
Autopilot index : 0
Autopilot for ship with nominally steady speed and heading
Label: Rudder
Maximum deflection   : 35.000 deg
Maximum velocity     : 3.000 deg/s
Maximum acceleration : Not set
Response frequency   : 3.000 rad/s
Response damping     : 0.850 rad/s (fraction of critical)
Maximum time step for computing deflections : 0.100

Autopilot gains
Diplacement gains have units of deg/m and deg/deg
Velocity gains have units of deg/(m/s) and deg/(deg/s)
Yaw gains given relative to earth-fixed axes (+yaw is clockwise)
                        Surge    Sway     Heave    Roll     Pitch    Yaw
Displacement gains :    0.000    0.000    0.000    0.000    0.000   -4.000
Velocity gains     :    0.000    0.000    0.000    0.000    0.000   -8.000

**** SEAKEEPING POSITION TRIM CONDITIONS ****

Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s


**** WAVE SPECTRUM ****

Bretschneider spectrum
Significant wave height :     3.250 m
Peak wave period        :     9.700 m
Long-crested seaway

Significant wave height based on point wave spectrum area :     3.229 m

Wave frequency       Spectral density
 (rad/s)                m2/(rad/s)
       0.200            0.000
       0.300            0.000
       0.400            0.010
       0.500            0.549
       0.600            1.365
       0.700            1.380
       0.800            1.034
       0.900            0.702
       1.000            0.465
       1.100            0.310
       1.200            0.210
       1.300            0.145
       1.400            0.102
       1.500            0.073
       1.600            0.053
       1.700            0.040
       1.800            0.030
       1.900            0.023
       2.000            0.018
```

```
 **** Motions at Ship CG in a Random Seaway ****

Bretschneider spectrum
Significant wave height :     3.250 m
Peak wave period        :     9.700 m
Long-crested seaway

Ship speed :    10.300 m/s  (20.000 knots, Froude number 0.300)
Sea direction (to) is relative to ship speed.
180 degrees for head seas, 90 degrees for seas from port
RMS Displacements and Zero-crossing Periods
Sea direction  Surge          Sway          Heave          Roll          Pitch          Yaw
      (deg)   (m)  (s)       (m)  (s)      (m)  (s)      (deg)  (s)    (deg)  (s)    (deg)  (s)
        0.0   2.74 37.6      0.00 46.4     0.23 26.6      0.00 26.2     0.61 25.1     0.00 38.1
       30.0   1.63 27.3      1.21 36.9     0.27 23.2      2.15 23.8     0.62 23.1     1.28 27.7
       60.0   0.48 15.1      0.45 15.8     0.44 15.1      7.95 13.7     0.53 14.4     1.68 13.9
       90.0   0.01  5.8      0.62  8.3     0.81  7.7      4.19  8.9     0.03  5.3     0.11  7.9
      120.0   0.14  7.6      0.31  7.3     0.76  6.3      1.44  6.5     1.05  5.7     0.33  6.0
      150.0   0.12  7.2      0.11  7.0     0.60  6.1      0.75  6.0     1.10  5.7     0.15  6.0
      180.0   0.11  7.1      0.00  6.9     0.54  6.0      0.00  7.7     1.06  5.7     0.00  5.9

Rudder RMS Deflections and Zero-crossing Periods
Values given for following rudders:
Rudder
Sea direction   Deflection Tz
    (deg)        (deg)    (s)
      0.0        0.00   37.3
     30.0        5.63   27.2
     60.0        8.96   13.8
     90.0        0.80    6.7
    120.0        2.88    5.6
    150.0        1.33    5.6
    180.0        0.00    5.5


Seakeeping at Position on Ship

Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s

RMS Motions at Seakeeping Position

Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s

 Sea direction  *** Longitudinal ***       *** Lateral ***        *** Vertical ***     *** Relative Vertical ***
```

	Disp	Tz	Acc	Disp	Tz	Acc	Disp	Tz	Acc	Disp	Tz	Vel
(deg)	(m)	(s)	(g)	(m)	(s)	(g)	(m)	(s)	(g)	(m)	(s)	(m/s)
0.0	2.68	37.9	0.009	0.00	47.6	0.000	0.54	25.9	0.009	0.70	17.6	0.025
30.0	1.61	27.5	0.010	1.45	31.4	0.007	0.50	23.1	0.006	0.61	20.6	0.019
60.0	0.45	15.2	0.008	0.93	14.3	0.019	0.57	14.6	0.011	0.75	13.8	0.035
90.0	0.00	6.4	0.001	0.77	7.7	0.059	0.92	7.8	0.071	0.31	5.3	0.038
120.0	0.08	6.6	0.010	0.46	7.1	0.042	1.28	6.0	0.159	1.20	4.6	0.166
150.0	0.07	5.9	0.011	0.16	6.9	0.017	1.25	5.8	0.159	1.44	4.5	0.204
180.0	0.07	5.6	0.011	0.00	7.4	0.000	1.21	5.8	0.154	1.45	4.4	0.211

Forces Relative to Local Axes and Motion-Induced Interruptions

MIIs given as rate for following duration : 60.0 s
Lateral tipping coefficient : 0.250
Longitudinal tipping coefficient : 0.170

Sea direction	***** Lateral *****			***** Longitudinal *****			Total
	Force estimator		MIIs	Force estimator		MIIs	MIIs
	RMS	Tz		RMS	Tz		
(deg)	(g)	(s)		(g)	(s)		
0.0	0.000	25.4	0.000	0.003	7.8	0.005	0.005
30.0	0.037	22.4	4.239	0.002	10.2	0.000	4.239
60.0	0.138	13.7	8.627	0.002	13.7	0.000	8.627
90.0	0.115	7.2	16.176	0.001	4.3	7.399	23.576
120.0	0.056	5.9	20.098	0.024	4.9	15.166	35.264
150.0	0.024	5.1	20.565	0.026	4.8	13.567	34.132
180.0	0.000	6.9	20.294	0.026	4.5	13.834	34.127

Wetness Calculations for Position Above Waterline

Wetness probability is given as probability per wave encounter.

Elevation relative to calm waterline : 7.800 m

Sea directio	** Relative vertical motion **			Wetness	
	RMS disp	Tz	RMS vel	P(wet)	Rate
(deg)	(m)	(s)	(m/s)	per enc	per hour
0.0	0.700	17.6	0.250	0.000000	0.000000
30.0	0.616	20.6	0.188	0.000000	0.000000
60.0	0.754	13.8	0.343	0.000000	0.000000
90.0	0.313	5.3	0.373	0.000000	0.000000
120.0	1.206	4.6	1.631	0.000000	0.000001
150.0	1.441	4.5	2.002	0.000000	0.000348
180.0	1.453	4.4	2.068	0.000001	0.000450

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Annex C: Files for Motions in a Fixed Seaway with SM3DSeakeepSeaway

C.1 Format of Input File for SM3DSeakeepSeaway

Record (a), Beginning Record

"begin SM3DSeakeepSeaway"(1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for run. This can include spaces.

Record (c), Input Ship Database File Name

"steadyShipDBFDFileName", steadyShipDBFDFileName (2 character strings)

"steadyShipDBFDFileName"	Record tag.
steadyShipDBFDFileName	Name of input ship database file in Python pickle format. This file must have been created using program SM3DBuildShip.

Record (d), Ship Loading Condition

"loadCondition", waterDensity, draftBlMid, trimBlStern, shipKG, correctionGM (1 character string, 5 floats)

"loadCondition"	Record tag.
waterDensity	Water density (kg/m^3).
draftBlMid	Draft of baseline at midships (m).
trimBlStern	Trim of baseline by stern (m).
shipKG	Height of centre of gravity above baseline (m).
correctionGM	Correction to metacentric height (m).
Note:	The values in this record must agree with the values used for the ship database file specified in Record (c) Values are considered to be in agreement when they are within a tolerance of 0.001 kg/m^3 for density, and 0.001 m for draft, trim, height of CG, and metacentric height. The output file from SM3DBuildShip gives the values of the above parameters.

Record (e), Beginning of Rudder Autopilot Settings.

"begin rudderAutopilotSettings" (2 character strings)

Records (e) to (e5) are optional.

"begin rudderAutopilotSettings"	Record tag.
Note:	Records (e) to (e5) are optional and can be used to supersede autopilot settings for a ship defined by SM3DBuildShip given in the file of (c). Within Records (e) to (e5), Records (e1) to (e4) can be repeated an arbitrary number of times to set rudder autopilot parameters as required.

Record (e1), Rudder Index for Autopilot Settings

"indexRudderAutopilot" indexRudderAutopilot (1 character string, 1 integer)

This Record must follow Record (e) if autopilot settings are being given as input.

"indexRudderAutopilot"	Record tag.
indexRudderAutopilot	Index of rudder for which autopilot settings are being specified. Rudder indices range from 0 to nRudder−1, where nRudder is the number of ship rudders. If this rudder to set to −1, then the input autopilot settings are applied to all rudders.

Record (e2), Rudder Autopilot Parameters

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"autopilotParam", deflectMaxDeg, velMaxDeg, accMaxDeg, freqResponse, dampResponse, dtMax (1 character string, 6 floats)

"autopilotControlParam"	Record tag.
deflectMaxDeg	Maximum rudder deflection angle (deg). This value is typically set to 35°. This parameter doesn't affect frequency domain computations with SM3DSeakeepSeaway.
velMaxDeg	Maximum rudder deflection velocity (deg/s). If this value is set to 0.0, then the maximum velocity is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepSeaway.
accMaxDeg	Maximum rudder acceleration (deg/s^2). If this value is set to 0.0, then the maximum acceleration is unlimited. This parameter doesn't affect frequency domain computations with SM3DSeakeepSeaway.
freqResponse	Undamped response frequency of rudder autopilot.
dampResponse	Damping of rudder autopilot as a fraction of critical damping. This value is typically between 0.5 and 1.0.
dtMax	Maximum time increment for time stepping of rudder motions. This parameter doesn't affect frequency domain computations with SM3DSeakeepSeaway.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e3), Rudder Autopilot Displacement Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"dispGains", surgeGain, swayGain, heaveGain, rollGain, pitchGain, yawGain (1 character string, 6 floats)

"dispGains"	Record tag.
surgeGain	Surge gain (deg/m). This value is typically 0.0.
swayGain	Sway gain (deg/m). This value is typically 0.0.
heaveGain	Heave gain (deg/m). This value is typically 0.0.
rollGain	Roll gain (deg/deg). This value is typically 0.0 unless rudder roll stabilization is desired.
pitchGain	Pitch gain (deg/deg). This value is typically 0.0.
yawGain	Yaw gain (deg/deg). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e4), Rudder Velocity Gains.

This record can optionally be entered if an autopilot index has been specified using Record (e1).

"velGains", surgeVelGain, swayVelGain, heaveVelGain, rollVelGain, pitchVelGain, yawVelGain (1 character string, 6 floats)

"velGains"	Record tag
surgeVelGain	Surge velocity gain (deg/(m/s)). This value is typically 0.0.
swayVelGain	Sway velocity gain (deg/(m/s)). This value is typically 0.0.
heaveVelGain	Heave velocity gain (deg/(m/s)). This value is typically 0.0.
rollVelGain	Roll velocity gain (deg/(deg/s)). This value is typically 0.0 unless rudder stabilization is desired.
pitchVelGain	Pitch velocity gain (deg/(deg/s)). This value is typically 0.0.
yawVelGain	Yaw velocity gain (deg/(deg/s)). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically ≤ 0.0.
Note:	If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

Record (e5), End of Rudder Autopilot Settings

"end rudderAutopilotSettings" (2 character strings)

"end rudderAutopilotSettings"	Record tag.

Record (f), Minimum Wave Encounter Frequency

"enFreqMinMotion", enFreqMinMotion (1 character string, 1 float)

"enFreqMinMotion"	Record tag.
enFreqMinMotion	Minimum wave encounter frequency for ship motion predictions. If the combination of ship speed, heading, and wave frequency gives an encounter frequency less than this value, then the wave frequency is shifted. This variable is used to avoid large amplitude motions at very low encounter frequencies.

Record (g1), Ship Speed Range in m/s

One of Records (g1) to (g6) must be given.

"speedRange", speedMin, speedMax, speedInc (1 character string, 3 floats)

"speedRange"	Record tag.
speedMin	Minimum ship speed (m/s).
speedMax	Maximum ship speed (m/s).
speedInc	Increment for ship speed (m/s).

Record (g2), Ship Speeds in m/s

One of Records (g1) to (g6) must be given.

"speeds", speeds (1 character string, array of floats)

"speeds"	Record tag.
speeds	Array of ship speeds (m/s).

Record (g3), Ship Speed Range in Knots

One of Records (g1) to (g6) must be given.

"speedKnotsRange", speedKnotsMin, speedKnotsMax, speedKnotsInc (1 character string, 3 floats)

"speedKnotsRange"	Record tag.
speedKnotsMin	Minimum ship speed (knots).
speedKnotsMax	Maximum ship speed (knots).
speedKnotsInc	Increment for ship speed (knots).

Record (g4), Ship Speeds in Knots

One of Records (g1) to (g6) must be given.

"speedsKnots", speedsKnots (1 character string, array of floats)

"speedsKnots"	Record tag.
speedsKnots	Array of ship speeds (knots).

Record (g5), Froude Number Range

One of Records (g1) to (g6) must be given.

"froudeRange", froudeMin, froudeMax, froudeInc (1 character string, 3 floats)

"froudeRange"	Record tag.
froudeMin	Minimum Froude number.
froudeMax	Maximum Froude number.
froudeInc	Froude number increment.

Record (g6), Ship Froude Numbers

One of Records (g1) to (g6) must be given.

"froudes", froudes (1 character string, array of floats)

"froudes"	Record tag.
froudes	Array of ship Froude numbers.

Record (h1), Range of Ship Headings

One of Records (h1) or (h2) must be given.

"shipHeadingRange", shipHeadingDegMin, shipHeadingDegMax, shipHeadingDegInc (1 character string, 3 floats)

"shipHeadingRange"	Record tag.
shipHeadingDegMin	Minimum ship heading (to, deg).
shipHeadingDegMax	Maximum ship heading (to, deg).
shipHeadingDegInc	Increment for ship heading (to, deg).
Note:	The ship heading convention is 0° for the ship heading north, 90° for the ship heading east.

Record (h2), Ship Headings

One of Records (h1) or (h2) must be given.

"shipHeadingsDeg", shipHeadingsDeg (1 character string, array of floats)

"shipHeadingsDeg"	Record tag.
shipHeadingsDeg	Array of ship headings (deg). The ship heading convention is 0° for the ship heading north, 90° for the ship heading east.

Record (i), Seaway Type

"spectrumType", spectrumType (2 character strings)

"spectrumType"	Record tag.
spectrumType	Type of seaway.
	uniSpectrum - Unidirectional seaway based on input spectrum.
	cosSpectrum - Directional spectrum describe by a point wave spectrum and cosine-squared spreading function.
	dirSpectrum - Directional seaway with specified directional properties.

Record (i1), Unidirectional Wave Spectrum Type

This record is required if spectrumType in Record (i) is set to uniSpectrum.

"uniSpectrumType", uniSpectrumType (2 character strings)

"uniSpectrumType"	Record tag.
uniSpectrumType	Type of unidirectional wave spectrum.
	uniBretschneider - Unidirectional Bretschneider wave spectrum.
	uniJONSWAP - Unidirectional JONSWAP wave spectrum.
	uniOchiHubble - Unidirectional Ochi and Hubble six parameter wave spectrum.
	uniInput - Unidirectional user-input wave spectrum.

Record (i2a), Unidirectional Bretschneider Spectrum Seaway Parameters

This record is required if uniSpectrumType in Record (i1) is set to uniBretschneider.

"uniBretParam", waveHeadingFromDeg, hs, tp (1 character string, 3 floats)

"uniBretParam"	Record tag.
waveHeadingFromDeg	Principal wave direction ν (from, degrees). 0° for waves from north, and 90° for waves from east.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).

Record (i2b), Unidirectional JONSWAP Spectrum Seaway Parameters

This record is required if uniSpectrumType in Record (i1) is set to uniJONSWAP.

"uniJONSWAPParam", waveHeadingFromDeg, hs, tp, peakEnhance (1 character string, 4 floats)

"uniJONSWAPParam"	Record tag.
waveHeadingFromDeg	Principal wave direction ν (from, degrees). 0° for waves from north, and 90° for waves from east.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).
peakEnhance	Peak enhancement factor γ. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.

Record (i2c), Unidirectional Ochi Hubble Spectrum Parameters

This record is required if uniSpectrumType in Record (i1) is set to uniOchiHubble.

"uniOchiHubbleParam", waveHeadingFromDeg, hs1, freqPeak1, spectralShape1, hs2, freqPeak2, spectralShape2 (1 character string, 7 floats)

"uniOchiHubbleParam"	Record tag.
waveHeadingFromDeg	Principal wave direction ν (from, degrees). 0° for waves from north, and 90° for waves from east.
hs1	Significant wave height h_{s-1} of wave system 1 (m).
freqPeak1	Peak wave frequency ω_{p-1} of wave system 1 (rad/s).
spectralShape1	Spectral shape factor λ_1 of wave system 1.
hs2	Significant wave height h_{s-2} of wave system 2 (m).
freqPeak2	Peak wave frequency ω_{p-2} of wave system 2 (rad/s).
spectralShape2	Spectral shape factor λ_2 of wave system 2.

Record (i2d), Unidirectional Input Spectrum Principal Wave Direction

This record is required if uniSpectrumType in Record (i1) is set to uniInput.

"uniInputDir", waveHeadingFromDeg (1 character string, 1 float)

"uniInputDir"	Record tag.
waveHeadingFromDeg	Principal wave direction ν (from, degrees). 0° for waves from north, and 90° for waves from east.

Record (i2e), Unidirectional Input Spectrum Wave Frequencies

This record is required if uniSpectrumType in Record (i1) is set to uniInput.

"uniInputWaveFreqs", uniInputWaveFreqs (1 character string, array of floats)

"uniInputWaveFreqs"	Record tag.
uniInputWaveFreqs	Wave frequencies ω_I for input energy densities (rad/s).

Record (i2f), Unidirectional Input Spectrum Energy Densities

This record is required if uniInputWaveDensities in Record (i1) is set to uniInput

"uniInputEnergyDensities", uniInputEnergyDensities (1 character string, array of floats)

"uniInputEnergyDensities"	Record tag.
uniInputEnergyDensities	Wave spectrum energy densities $S_{\omega_I}(\omega_I)$ corresponding to wave frequencies of Record (i2e).

Record (i3), Cosine-Squared Wave Spectrum Type

This record is required if spectrumType in Record (i) is set to cosSpectrum.

"cosSpectrumType", cosSpectrumType (2 character strings)

"cosSpectrumType"	Record tag.
cosSpectrumType	Type of wave spectrum with cosine-squared directional spreading. cosBretschneider - Bretschneider wave spectrum with cosine-squared directional spreading. cosJONSWAP - JONSWAP wave spectrum with cosine-squared directional spreading.

Record (i3a), Cosine-squared Bretschneider Spectrum Parameters

This record is required if cosSpectrumType in Record (i3) is set to cosBretschneider.

"cosBretParam", waveHeadingFromDeg, hs, tp, spreadAngleDeg (1 character string, 4 floats)

"cosBretParam"	Record tag.
waveHeadingFromDeg	Principal wave direction $\overline{\nu}$ (from, degrees). 0° for waves from north, and 90° for waves from east.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).
spreadAngleDeg	Directional spreading angle γ_s (deg).

Record (i3b), Cosine-squared JONSWAP Spectrum Seaway Parameters

This record is required if cosSpectrumType in Record (i3) is set to cosJONSWAP.

"cosJONSWAPParam", waveHeadingFromDeg, hs, tp, peakEnhance, spreadAngleDeg (1 character string, 5 floats)

"cosJONSWAPParam"	Record tag.
waveHeadingFromDeg	Principal wave direction $\overline{\nu}$ (from, degrees). 0° for waves from north, and 90° for waves from east.
hs	Significant wave height H_s (m).
tp	Peak wave period T_p (s).
peakEnhance	Peak enhancement parameter γ. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.
spreadAngleDeg	Directional spreading angle (deg).

Record (i4), Directional Wave Spectrum Type

This record is required if spectrumType in Record (i) is set to dirSpectrum.

"dirSpectrumType", dirSpectrumType (2 character strings)

"dirSpectrumType"	Record tag.
dirSpectrumType	Type of unidirectional wave spectrum: tenParameter - Ten parameter spectrum from Hogben and Cobb [11]. EndecoWaveBuoy - Directional spectrum from Endeco wave buoy. inputDir - Input directional spectrum.

Record (i4a), Ten Parameter Spectrum Parameters

This record is required if dirSpectrumType in Record (i4) is set to tenParameter.

"tenParamParam", hs1, freqPeak1, spectralShape1, waveHeadingMeanDeg1, dirSpreadExp1, hs2, freqPeak2, spectralShape2, waveHeadingMeanDeg2, dirSpreadExp2 (1 character string, 10 floats)

"tenParamParam"	Record tag.
hs1	Significant wave height h_{s-1} of wave system 1 (m).
freqPeak1	Peak wave frequency ω_{p-1} of wave system 1 (rad/s).
spectralShape1	Spectral shape factor λ_1 of wave system 1.
waveHeadingMeanDeg1	Principle wave direction $\overline{\nu_1}$ (from, degrees) of wave systems 1. 0° for waves from north, and 90° for waves from east.
dirSpreadExp1	Directional spreading exponent P_1 of wave system 1.
hs2	Significant wave height h_{s-2} of wave system 2 (m).
freqPeak2	Peak wave frequency ω_{p-2} of wave system 2 (rad/s).
spectralShape2	Spectral shape factor λ_2 of wave system 2.
waveHeadingMeanDeg2	Principle wave direction $\overline{\nu_2}$ (from, degrees) of wave systems 2. 0° for waves from north, and 90° for waves from east.
dirSpreadExp2	Directional spreading exponent P_2 of wave system 2.

Record (i5), Endeco Wave Buoy Spectrum File Name

This record is required if spectrumType in Record (i) is set to EndecoWaveBuoy.

"EndecoSpectrumFileName", EndecoSpectrumFileName (2 character strings)

"EndecoSpectrumFileName"	Record tag.
EndecoSpectrumFileName	File name of directional wave spectrum file produced by Endeco 956 or 1156 wave buoy. The file name will typically have the extension ".std".

Record (i6), Input Directional Wave Spectrum File Name

This record is required if spectrumType in Record (i) is set to inputDir.

"inputDirSpectrumFileName", inputDirSpectrumFileName (2 character strings)

"inputDirSpectrumFileName"	Record tag.
inputDirSpectrumFileName	Input directional wave spectrum file name. The format of the directional wave spectrum file is given in Annex C.4.

Record (j1), Range of Incident Wave Frequencies for Integration of Ship Motion Spectrum

One of Records (j1) or (j2) must be given.

"waveFreqRange", waveFreqMin, waveFreqMax, waveFreqInc (1 character string, 3 floats)

"waveFreqRange"	Record tag.
waveFreqMin	Minimum incident wave frequency (rad/s).
waveFreqMax	Maximum incident wave frequency (rad/s).
waveFreqInc	Increment for incident wave frequency (rad/s).

Record (j2), Incident Wave Frequencies for Integration of Ship Motion Spectrum

One of Records (j1) or (j2) must be given.

"waveFreqs", waveFreqs (1 character string, array of floats)

"waveFreqs"	Record tag.
waveFreqs	Array of increasing incident wave frequencies (rad/s).

Record (k1), Wave Direction Range for Integration of Ship Motion Spectrum

If spectrumType in Record (i) is set to cosSpectrum or dirSpectrum, then one of Records (k1) or (k2) must be given.

"waveDirFromRange", waveDirFromDegMin, waveDirFromDegMax, waveDirFromDegInc (1 character string, 3 floats)

"waveDirFromRange"	Record tag.
waveDirFromDegMin	Minimum wave direction (deg).
waveDirFromDegMax	Maximum wave direction (deg).
waveDirFromDegInc	Wave direction increment (deg).
Note:	Wave directions are given using a convention of 0° for waves from north, 90° for waves from east.

Record (k2), Wave Directions Integration of Ship Motion Spectrum

If spectrumType in Record (i) is set to cosSpectrum or dirSpectrum, then one of Records (k1) or (k2) must be given.

"waveDirsFrom", waveDirsFromDeg (1 character string, array of floats)

"waveDirsFrom"	Record tag.
waveDirsFromDeg	Wave directions for integration of ship motion spectrum. Wave directions are given using a convention of 0° for waves from north, 90° for waves from east.

Record (l), Beginning of Steady Wave Data

This record is optional.

"begin steadyWaveData" (1 character string with 2 words)

Record (l1), Number of Speeds for Steady Wave Input Data

This record is required if a steady wave data is being specified.

"nSpeedStation", nSpeedSteady, nStationSteady (1 character string, 2 integers)

"nSpeedStation"	Record tag.
nSpeedSteady	Number of speeds for which steady wave data are being specified. This value must be ≥ 1.
nStationSteady	Number of stations for which steady wave profile data are being specified. If this value is 0, then no steady wave profile data are specified.

Record (l2a), Speeds in m/s for Steady Wave Data

One of Records (l2a), (l2b), or (l2c) are required if steady wave data are being given.

"speedsSteady", speedsSteady (1 character string, nSpeedSteady floats)

"speedsSteady"	Record tag.
speedsSteady	Ship speeds for steady wave data (m/s).

Record (l2b), Speeds in Knots for Steady Wave Data

One of Records (l2a), (l2b), or (l2c) are required if steady wave data are being given.

"speedsKnotsSteady", speedsKnotsSteady (1 character string, nSpeedSteady floats)

"speedsKnotsSteady"	Record tag.
speedsKnotsSteady	Ship speeds for steady wave data (knots).

Record (l2c), Froude numbers for Steady Wave Data

One of Records (l2a), (l2b), or (l2c) are required if steady wave data are being given.

"froudesSteady", froudesSteady (1 character string, nSpeedSteady floats)

"froudesSteady"	Record tag.
froudesSteady	Froude numbers for steady wave data.

Record (l3), Ship Steady Heave (Sinkage) Data

This record is required if steady wave data are being given.

"heavesSteady", heavesSteady (1 character string, nSpeedSteady floats)

"heavesSteady"	Record tag.
heavesSteady	Ship heave values (m, + up) for steady ship speeds.

Record (l4), Ship Steady Pitch (Trim) Data

This record is required if steady wave data are being given.

"pitchsSteady", pitchsSteadyDeg (1 character string, nSpeedSteady floats)

"pitchsSteady"	Record tag.
pitchsSteadyDeg	Ship pitch values (deg, + bow down) for steady ship speeds.

Record (l5), Steady Wave Elevation Profile Data

This record must be given nStationSteady times, where nStationSteady is the number of stations specified in Record (l1).

"stationWaveElevsSteady", stationSteady, waveElevsSteady (1 character string, 1 + nSpeedSteady floats)

"stationWaveElevsSteady"	Record tag.
stationSteady	Station number for input wave elevations.
waveElevsSteady	Wave elevations (m) at stationSteady for ship speeds specified in Record (l2a), (l2b), or (l2c).

Record (m), End of Steady Wave Data

This record is required if Record (m) and subsequent records have been entered.

"end steadyWaveData" (1 character string with 2 words)

Record (n), Beginning of Seakeeping Position Data

This record is optional.

"begin seakeepPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (n1) to (n7f) giving seakeeping position parameters. Record (o) must follow at the end of all seakeeping position data.

Record (n1), Seakeeping Position Label

This record is required if a seakeeping position is being specified.

(2 character strings)

"labelPos"	Record tag.
labelPos	Label for seakeeping position. This can include spaces.

Record (n2), Seakeeping Position Location

This record is required if a seakeeping position is being specified.

(1 character string, 3 floats)

"locationPos"	Record tag.
stationPos	Station for seakeeping position. Station 0 is at the fore perpendicular.
yPos	Lateral coordinate (+ port) relative to ship centreline (m).
zBlPos	Vertical coordinate (+ up) relative to ship baseline (m).

Record (n3), Option for Including Radiation and Diffraction when Evaluating Relative Vertical Motion

This record is optional if a seakeeping position is being specified.

"relMoRadDifOption" relMoRadDifOption (2 character strings)

"relMoRadDifOption"	Record tag.
relMoRadDifOption	Option for including radiation and diffraction in relative vertical motion: noRadDif - Wave radiation and diffraction are not considered when evaluating relative wave motion (default). nearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the seakeeping position location specified in Record (n2). wlNearestPanel - Wave radiation and diffraction are evaluated based on the panel centroid nearest to the waterline plane location specified by the longitudinal and lateral coordinates in Record (n2). direct - Wave radiation and diffraction are evaluated directly at the seakeeping position location specified in Record (n2). If the seakeeping position is above the calm waterline, then the vertical position for wave elevation is evaluated at the calm waterline. wlDirect - Wave radiation and diffraction are evaluated directly at the waterline plane location specified by the longitudinal and lateral coordinates in Record (n2).
Note:	If radiation and diffraction computations are to be included in relative motion computations (relMoRadDifOption set to nearestPanel, wlNearestPanel, direct, or wlDirect), then the ship database specified in Record (c) must have a hull radiation and diffraction database that includes velocity potentials and source strengths.

Record (n4), Option for Including the Steady Wave Due to Ship Forward Speed when Evaluating Wetness or Emergence Events

This record is optional if a seakeeping position is being specified.

"relMoSteadyWaveOption", relMoSteadyWaveOption (2 character strings)

"relMoSteadyWaveOption"	Record tag.
relMoSteadyWaveOption	Option for including the influence of the steady wave field due to ship forward speed when evaluating distance from the waterline in calm water: noSteadyWave - The steady wave due to ship forward speed is not included (default). This option must be used if no steady wave data are provided in Records (l) to (m). sinkageTrimOnly - The ship sinkage and trim due to ship forward speed are included when evaluated vertical position relative to the calm waterline. Sinkage and trim values specified in input Records (l3) and (l4). steadyWaveElev - The steady wave elevation is evaluated based on the input steady wave profile specified in Records (l5).

Record (n5), Option for Motion-Induced Interruptions

This record is required if a seakeeping position is being specified.

"miiOption", miiOption (2 character strings)

"miiOption"	Record tag.
miiOption	Option for motion-induced interruption computations: mii - Motion-induced interruption computations are performed. noMii - No motion-induced interruption computations are performed.

Record (n6), Parameters for Motion-Induced Interruptions

This record is required if miiOption is set to mii in Record (n5).

"miiParam", tipCoLat, tipCoLong, durationMii (1 character strings, 3 floats)

"miiParam"	Record tag.
tipCoLat	Lateral tipping coefficient. A value of 0.25 is typically used for humans facing forward.
tipCoLong	Longitudinal tipping coefficient. A value of 0.17 is typically used for humans facing forward.
durationMii	Duration for computing incidence of motion-induced interruptions (s). A value of 60 s is typically used.
Note:	For sliding calculations, the user should set tipCoLat and tipCoLong equal to the static coefficient of friction.

Record (n7), Option for Slamming, Deck Wetness, or Emergence Computations

This record is required if a seakeeping position is being specified.

"slamWetEmergeOption", slamWetEmergeOption (2 character strings)

"slamWetEmergeOption"	Record tag.
slamWetEmergeOption	Option for slamming, deck wetness, or emergence computations: noSlamWetEmerge - No slamming, deck wetness, or emergence computations are performed. slamPressureCoWidth - Slamming calculations are performed using an input slamming form factor and effective pressure width specified in Record (n7b). slamWedge - Slamming calculations are performed using wedge dimensions given in Record (n7c). slamOffsets - Slamming calculations are performed using offsets given in Records (n7d), (n7e), and (n7f). wetnessEmerge - Incidence of wetness or emergence calculations are performed, depending on whether the position is above or below the waterline.

Record (n7a), Duration and Exceedence Probability for Slamming Statistics

This record is required if slamWetEmergeOption in Record (n7) is set to slamPressureCoWidth, slamWedge, or slamOffsets.

"durationPExSlam", durationSlamHours, pExceedSlam (1 character string, 2 floats)

"durationPExSlam"	Record tag.
durationSlamHours	Duration for slamming statistics (hours).
pExceedSlam	Exceedence probability for slamming statistics.

Record (n7b), Slamming Pressure Coefficient and Effective Pressure Width

This record is required if slamWetEmergeOption in Record (n7) is set to slamPressureCoWidth.

"slamPressureCoWidth", slamPressureCo, slamForceWidth (1 character string, 2 floats)

"slamPressureCoWidth"	Record tag.
slamPressureCo	Slamming pressure coefficient.
slamForceWidth	Effective slamming force width (m).

Record (n7c), Wedge Geometry for Slamming Calculations

This record is required if slamWetEmergeOption in Record (n7) is set to slamWedge.

"slamWedge", deadRiseDeg, slamForceHeight (1 character string, 2 floats)

"slamWedge"	Record tag.
deadRiseDeg	Hull deadrise angle at keel (degrees). This value must be greater than 0 degrees. For deadrise angles less than 5 degrees, this approach can be inaccurate, and is recommended that either the slamForm or slamOffsets option be used instead for slamWetEmergeOption in Record (n7).
slamForceHeight	Height above the keel at which slamming pressure goes to zero (typically taken as $0.1T_x$).

Record (n7d), Elevation Above Baseline for Zero Slamming Pressure

This record is required if slamWetEmergeOption in Record (n7) is set to slamOffsets.

"zBlZeroSlamPres", zBlZeroSlamPres (1 character string, 1 float)

"zBlZeroSlamPres"	Record tag.
zBlZeroSlamPres	Elevation above baseline at which slamming pressure goes to zero (m). This value is typically assumed to be at a height of $0.1T_x$ above the baseline, where T_x is sectional draft.

Record (n7e), Y Offsets for Performing Slamming Calculations

This record is required if slamWetEmergeOption in Record (n7) is set to slamOffsets.

"yOffsetsSlam", yOffsetsSlam (1 character string, array of floats)

"yOffsetsSlam"	Record tag.
yOffsetsSlam	Horizontal offsets for points going from keel to at least zBlZeroSlamPres (Record (n7d)) above the baseline (m).

Record (n7f), Z Offsets for Performing Slamming Calculations

This record is required if slamWetEmergeOption in Record (n7) is set to slamOffsets.

"zBlOffsetsSlam", zBlOffsetsSlam (1 character string, array of floats)

"zBlOffsetsSlam"	Record tag.
zBlOffsetsSlam	Vertical offsets for points going from keel to at least zBlZeroSlamPres (Record (n7d)) above the baseline (m).

Record (o), End of Seakeeping Position Data

This record is required if Record (n) is present.

"end seakeepPositions" (1 character string with 2 words)

Record (p), End Record

"end SM3DSeakeepSeaway"(1 character string with 2 words)

C.2 Sample Input File for SM3DSeakeepSeaway

```
begin SM3DSeakeepSeaway
label Generic frigate
steadyShipDBFDFileName genFrigFDShip.pkl
loadCondition 1025.0 4.2 0.0 6.0 0.0
enFreqMinMotion 0.1
speedKnotsRange 10.0 10.0 10.0
shipHeadingRange 0.0 345.0 15.0
spectrumType dirSpectrum
dirSpectrumType tenParameter
tenParamParam 3.0 0.628 1.0 110.0 1.0 4.0 0.419 1.0 160.0 1.0
waveFreqRange 0.2 2.0 0.05
waveDirFromRange 0.0 360.0 10.0
begin seakeepPositions
    labelPos Bridge
    locationPos 3.0 2.0 12.0
    relMoRadDifOption noRadDif
    relMoSteadyWaveOption noSteadyWave
    miiOption mii
    miiParam 0.25 0.17 60.0
    slamWetEmergeOption wetnessEmerge
end seakeepPositions
end SM3DSeakeepRelative
```

C.3 Sample Output File for SM3DSeakeepSeaway

```
Program SM3DSeakeepSeaway
ShipMo3D library Version 1.0c - 26 November 2007
Time : Wed Feb 06 15:42:23 2008
Run label:
Generic frigate

**** ECHO OF USER INPUT ****

Input ship database for frequency domain computation file name:
genFrigFDShip.pkl

Ship Loading Condition
Water density : 1025.000 kg/m3
Draft of baseline at midships       :     4.200 m
Trim of baseline by stern           :     0.000 m
Height of CG above baseline, KG     :     6.000 m
Correction to metacentric height GM :     0.000 m

Minimum wave encounter frequency for predicting ship motions : 0.100 rad/s

Speed range
Minimum   :   10.000 knots
Maximum   :   10.000 knots
Increment :   10.000 knots

Sea direction range
Minimum   :    0.000 deg
Maximum   :  345.000 deg
Increment :   15.000 deg

Seaway
Spectrum type :  dirSpectrum
Directional spectrum type :  tenParameter
Ten parameter spectrum parameters
Wave system                      1             2
Significant wave height     :     3.000 m         4.000 m
Peak wave frequency         :     0.628 rad/s     0.419 rad/s
Spectral shape factor       :     1.000           1.000
Mean wave direction (from)  :   110.000 deg     160.000 deg
Directional spread exponent :     1.000           1.000

Incident wave frequency range for integration of ship motion spectra
Minimum   :    0.200 rad/s
Maximum   :    2.000 rad/s
Increment :    0.050 rad/s

Incident wave direction range (from) for integration of ship motion spectra
Minimum   :    0.000 deg
Maximum   :  360.000 deg
Increment :   10.000 deg

Seakeeping Positions

Label               : Bridge
Station             :     3.000
Lateral offset y    :     2.000 m (+ port)
Vertical offset zBl :    12.000 m (+ up, relative to baseline)
Option for including radiation and diffraction for relative motion (input) : noRadDif
Option for including steady wave due to ship forward speed (input) : noSteadyWave
Option for motion-induced interruption computations :  mii
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
```

```
Longitudinal tipping coefficient :     0.170
Duration for MII incidence       :      60.0 s
Option for slamming, wetness, or emergence computations :  wetnessEmerge

**** SHIP LOADING CONDITION ****

Generic frigate
Load Condition Properties for Trimmed Ship

Summary of hydrostatic properties
Number of panels on port side        :          624
Length between perpendiculars        :      120.000 m
Draft of baseline at midships        :        4.200 m
Trim of baseline by stern            :        0.000 m
Beam based on maximum y value        :       14.115 m
Volume                               :     3625.687 m3
Water density                        :     1025.000 kg/m3
Mass                                 : 3716329.367494 kg
LCB of aft of FP (m)                 :       61.739 m
X origin aft of FP (m)               :       61.739 m
X value of LCB                       :        0.000 m
Center of buoyancy wrt waterline     :       -1.620 m
Wetted surface area                  :     1754.193 m2
Waterplane area                      :     1344.547 m2
X value of center of floatation      :       -5.016 m
Integral of waterplane area*X**2     :  1235150.552 m4
Integral of waterplane area*Y**2     :    17543.034 m4
KG, height of CG above baseline      :        6.000 m
Height of CG above waterline         :        1.800 m
Metacentric height from hydrostatics :        1.418 m

Inertial Properties

Inertia matrix, units of kg, kg*m, and kg*m2
   3716329.4          0.0          0.0          0.0          0.0          0.0
         0.0    3716329.4          0.0          0.0          0.0          0.0
         0.0          0.0    3716329.4          0.0          0.0          0.0
         0.0          0.0          0.0   85624228.6          0.0          0.0
         0.0          0.0          0.0          0.0 3344696430.7          0.0
         0.0          0.0          0.0          0.0          0.0 3344696430.7

Roll radius of gyration  :     4.800 m
Pitch radius of gyration :    30.000 m
Yaw radius of gyration   :    30.000 m

Roll Metacentric Height Properities

Correction to roll metacentric height :     0.000 m
Corrected metacentric height          :     1.418 m


Roll Properties at Zero Forward Speed

Roll added mass                       : 19312942.233901 kg*m**2
Nondimensional roll added mass A44/I44 :     0.226
Natural roll frequency                :     0.702 rad/s
Natural roll period                   :     8.953 s


**** SHIP AUTOPILOT SETTINGS ****

Generic frigate
Autopilots for Ship
```

```
Autopilot index : 0
Autopilot for ship with nominally steady speed and heading
Label: Rudder
Maximum deflection   : 35.000 deg
Maximum velocity     : 3.000 deg/s
Maximum acceleration : Not set
Response frequency   : 3.000 rad/s
Response damping     : 0.850 rad/s (fraction of critical)
Maximum time step for computing deflections : 0.100

Autopilot gains
Diplacement gains have units of deg/m and deg/deg
Velocity gains have units of deg/(m/s) and deg/(deg/s)
Yaw gains given relative to earth-fixed axes (+yaw is clockwise)
                        Surge    Sway     Heave    Roll     Pitch    Yaw
Displacement gains :    0.000    0.000    0.000    0.000    0.000   -4.000
Velocity gains     :    0.000    0.000    0.000    0.000    0.000   -8.000

**** SEAKEEPING POSITION TRIM CONDITIONS ****

Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s


**** DIRECTIONAL WAVE SPECTRUM ****

Ten parameter directional wave spectrum
Significant wave height  :     5.000 m
Wave system                    1               2
Significant wave height        :     3.000 m         4.000 m
Peak wave frequency            :     0.628 rad/s     0.419 rad/s
Spectral shape parameter       :     1.000 deg       1.000 deg
Mean wave direction (from)     :   110.000         160.000
Directional spreading exponent :     1.000           1.000
Significant wave height based on directional wave spectrum area :     4.992 m

Wave frequency       Spectral density
 (rad/s)                m2/(rad/s)
       0.200            0.000
       0.250            0.008
       0.300            0.545
       0.350            2.252
       0.400            3.363
       0.450            3.471
       0.500            3.286
       0.550            3.048
       0.600            2.727
       0.650            2.339
       0.700            1.939
       0.750            1.572
       0.800            1.259
       0.850            1.002
       0.900            0.797
       0.950            0.635
       1.000            0.508
```

1.050	0.409
1.100	0.331
1.150	0.270
1.200	0.221
1.250	0.182
1.300	0.151
1.350	0.126
1.400	0.106
1.450	0.089
1.500	0.076
1.550	0.064
1.600	0.055
1.650	0.047
1.700	0.041
1.750	0.035
1.800	0.031
1.850	0.027
1.900	0.024
1.950	0.021
2.000	0.018

Directional energy densities (m2/(rad/s)/deg)

Frequency	Wave directions (from, deg)							
(rad/s)	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
0.200	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.250	0.000001	0.000003	0.000005	0.000008	0.000011	0.000015	0.000019	0.000023
0.300	0.000091	0.000203	0.000354	0.000541	0.000757	0.000996	0.001251	0.001514
0.350	0.000378	0.000838	0.001464	0.002235	0.003128	0.004116	0.005169	0.006255
0.400	0.000599	0.001293	0.002231	0.003386	0.004721	0.006197	0.007768	0.009387
0.450	0.000925	0.001690	0.002696	0.003913	0.005304	0.006827	0.008436	0.010081
0.500	0.001586	0.002423	0.003463	0.004676	0.006023	0.007465	0.008958	0.010456
0.550	0.002235	0.003132	0.004191	0.005380	0.006662	0.008000	0.009352	0.010677
0.600	0.002540	0.003429	0.004443	0.005552	0.006723	0.007920	0.009106	0.010246
0.650	0.002498	0.003310	0.004220	0.005198	0.006216	0.007242	0.008246	0.009197
0.700	0.002248	0.002949	0.003725	0.004551	0.005402	0.006253	0.007078	0.007851
0.750	0.001919	0.002503	0.003144	0.003821	0.004516	0.005206	0.005870	0.006489
0.800	0.001590	0.002066	0.002585	0.003132	0.003690	0.004243	0.004772	0.005263
0.850	0.001296	0.001679	0.002097	0.002535	0.002981	0.003420	0.003841	0.004229
0.900	0.001048	0.001356	0.001690	0.002040	0.002395	0.002745	0.003079	0.003386
0.950	0.000846	0.001093	0.001360	0.001640	0.001924	0.002203	0.002468	0.002712
1.000	0.000683	0.000882	0.001097	0.001321	0.001549	0.001772	0.001984	0.002179
1.050	0.000553	0.000714	0.000887	0.001068	0.001251	0.001431	0.001601	0.001758
1.100	0.000450	0.000581	0.000721	0.000868	0.001016	0.001161	0.001299	0.001426
1.150	0.000368	0.000475	0.000589	0.000709	0.000830	0.000948	0.001060	0.001163
1.200	0.000303	0.000390	0.000484	0.000582	0.000681	0.000778	0.000870	0.000954
1.250	0.000250	0.000322	0.000400	0.000481	0.000562	0.000642	0.000718	0.000787
1.300	0.000208	0.000268	0.000332	0.000399	0.000467	0.000533	0.000596	0.000654
1.350	0.000174	0.000224	0.000278	0.000334	0.000390	0.000445	0.000498	0.000546
1.400	0.000146	0.000188	0.000233	0.000280	0.000328	0.000374	0.000418	0.000458
1.450	0.000123	0.000159	0.000197	0.000237	0.000277	0.000316	0.000353	0.000387
1.500	0.000105	0.000135	0.000167	0.000201	0.000235	0.000268	0.000299	0.000328
1.550	0.000089	0.000115	0.000142	0.000171	0.000200	0.000228	0.000255	0.000279
1.600	0.000076	0.000098	0.000122	0.000147	0.000171	0.000195	0.000218	0.000239
1.650	0.000066	0.000085	0.000105	0.000126	0.000147	0.000168	0.000188	0.000206
1.700	0.000057	0.000073	0.000091	0.000109	0.000127	0.000145	0.000162	0.000178
1.750	0.000049	0.000063	0.000079	0.000094	0.000110	0.000126	0.000141	0.000154
1.800	0.000043	0.000055	0.000068	0.000082	0.000096	0.000110	0.000122	0.000134
1.850	0.000037	0.000048	0.000060	0.000072	0.000084	0.000096	0.000107	0.000117
1.900	0.000033	0.000042	0.000052	0.000063	0.000074	0.000084	0.000094	0.000103
1.950	0.000029	0.000037	0.000046	0.000055	0.000065	0.000074	0.000082	0.000090
2.000	0.000025	0.000033	0.000041	0.000049	0.000057	0.000065	0.000073	0.000080

Frequency	Wave directions (from, deg)							
(rad/s)	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0
0.200	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

0.250	0.000027	0.000031	0.000034	0.000037	0.000040	0.000043	0.000044	0.000045
0.300	0.001777	0.002032	0.002272	0.002488	0.002674	0.002826	0.002937	0.003006
0.350	0.007341	0.008394	0.009382	0.010275	0.011046	0.011672	0.012132	0.012414
0.400	0.011005	0.012572	0.014041	0.015367	0.016510	0.017436	0.018115	0.018528
0.450	0.011713	0.013282	0.014740	0.016043	0.017152	0.018032	0.018658	0.019010
0.500	0.011913	0.013286	0.014533	0.015615	0.016500	0.017161	0.017578	0.017739
0.550	0.011935	0.013087	0.014099	0.014940	0.015585	0.016013	0.016212	0.016175
0.600	0.011305	0.012250	0.013054	0.013690	0.014142	0.014393	0.014438	0.014273
0.650	0.010065	0.010826	0.011454	0.011932	0.012245	0.012384	0.012343	0.012125
0.700	0.008549	0.009152	0.009639	0.009998	0.010217	0.010288	0.010211	0.009987
0.750	0.007043	0.007516	0.007893	0.008163	0.008318	0.008353	0.008267	0.008062
0.800	0.005700	0.006071	0.006362	0.006567	0.006679	0.006694	0.006611	0.006434
0.850	0.004573	0.004863	0.005090	0.005246	0.005328	0.005332	0.005259	0.005111
0.900	0.003658	0.003885	0.004062	0.004183	0.004244	0.004244	0.004181	0.004059
0.950	0.002927	0.003107	0.003247	0.003341	0.003387	0.003384	0.003332	0.003232
1.000	0.002350	0.002493	0.002604	0.002678	0.002713	0.002709	0.002666	0.002584
1.050	0.001895	0.002010	0.002098	0.002157	0.002184	0.002180	0.002144	0.002078
1.100	0.001537	0.001629	0.001700	0.001747	0.001769	0.001765	0.001735	0.001681
1.150	0.001253	0.001328	0.001385	0.001423	0.001441	0.001437	0.001413	0.001368
1.200	0.001028	0.001089	0.001136	0.001167	0.001181	0.001178	0.001157	0.001120
1.250	0.000848	0.000899	0.000937	0.000962	0.000974	0.000971	0.000954	0.000923
1.300	0.000704	0.000746	0.000777	0.000798	0.000808	0.000805	0.000791	0.000766
1.350	0.000588	0.000622	0.000649	0.000666	0.000674	0.000672	0.000660	0.000639
1.400	0.000493	0.000522	0.000545	0.000559	0.000565	0.000564	0.000554	0.000536
1.450	0.000416	0.000441	0.000459	0.000472	0.000477	0.000475	0.000467	0.000452
1.500	0.000353	0.000374	0.000390	0.000400	0.000404	0.000403	0.000396	0.000383
1.550	0.000301	0.000319	0.000332	0.000341	0.000345	0.000343	0.000337	0.000326
1.600	0.000258	0.000273	0.000284	0.000292	0.000295	0.000294	0.000289	0.000279
1.650	0.000221	0.000234	0.000244	0.000251	0.000254	0.000253	0.000248	0.000240
1.700	0.000191	0.000202	0.000211	0.000217	0.000219	0.000218	0.000214	0.000207
1.750	0.000166	0.000176	0.000183	0.000188	0.000190	0.000189	0.000186	0.000180
1.800	0.000144	0.000153	0.000159	0.000163	0.000165	0.000165	0.000162	0.000156
1.850	0.000126	0.000133	0.000139	0.000143	0.000144	0.000144	0.000141	0.000136
1.900	0.000110	0.000117	0.000122	0.000125	0.000126	0.000126	0.000124	0.000120
1.950	0.000097	0.000103	0.000107	0.000110	0.000111	0.000111	0.000109	0.000105
2.000	0.000086	0.000091	0.000094	0.000097	0.000098	0.000098	0.000096	0.000093

Frequency	Wave directions (from, deg)							
(rad/s)	160.0	170.0	180.0	190.0	200.0	210.0	220.0	230.0
0.200	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.250	0.000046	0.000045	0.000044	0.000043	0.000040	0.000037	0.000034	0.000031
0.300	0.003029	0.003006	0.002937	0.002826	0.002674	0.002488	0.002272	0.002032
0.350	0.012509	0.012414	0.012132	0.011671	0.011046	0.010275	0.009382	0.008394
0.400	0.018661	0.018512	0.018084	0.017390	0.016452	0.015297	0.013962	0.012486
0.450	0.019076	0.018857	0.018357	0.017592	0.016586	0.015369	0.013977	0.012454
0.500	0.017638	0.017278	0.016670	0.015834	0.014794	0.013581	0.012233	0.010791
0.550	0.015904	0.015408	0.014700	0.013803	0.012744	0.011555	0.010272	0.008935
0.600	0.013906	0.013346	0.012611	0.011723	0.010708	0.009599	0.008428	0.007231
0.650	0.011736	0.011187	0.010496	0.009684	0.008775	0.007796	0.006779	0.005752
0.700	0.009624	0.009132	0.008525	0.007824	0.007048	0.006222	0.005371	0.004520
0.750	0.007745	0.007325	0.006815	0.006231	0.005590	0.004913	0.004218	0.003528
0.800	0.006168	0.005821	0.005402	0.004926	0.004407	0.003860	0.003302	0.002749
0.850	0.004892	0.004609	0.004271	0.003887	0.003470	0.003032	0.002586	0.002146
0.900	0.003881	0.003652	0.003379	0.003071	0.002737	0.002387	0.002032	0.001682
0.950	0.003087	0.002903	0.002683	0.002436	0.002169	0.001889	0.001605	0.001327
1.000	0.002467	0.002318	0.002142	0.001943	0.001728	0.001503	0.001276	0.001053
1.050	0.001983	0.001862	0.001719	0.001559	0.001385	0.001204	0.001021	0.000842
1.100	0.001603	0.001505	0.001389	0.001259	0.001118	0.000971	0.000823	0.000678
1.150	0.001304	0.001224	0.001129	0.001023	0.000908	0.000789	0.000668	0.000550
1.200	0.001068	0.001002	0.000924	0.000837	0.000743	0.000645	0.000546	0.000449
1.250	0.000880	0.000826	0.000761	0.000689	0.000612	0.000531	0.000449	0.000369
1.300	0.000730	0.000684	0.000631	0.000571	0.000507	0.000440	0.000372	0.000306
1.350	0.000609	0.000571	0.000526	0.000476	0.000422	0.000366	0.000310	0.000254
1.400	0.000510	0.000479	0.000441	0.000399	0.000354	0.000307	0.000260	0.000213
1.450	0.000430	0.000404	0.000372	0.000336	0.000298	0.000259	0.000219	0.000180

1.500	0.000365	0.000342	0.000315	0.000285	0.000253	0.000219	0.000185	0.000152
1.550	0.000311	0.000291	0.000268	0.000243	0.000215	0.000187	0.000158	0.000129
1.600	0.000266	0.000249	0.000230	0.000208	0.000184	0.000160	0.000135	0.000111
1.650	0.000229	0.000214	0.000197	0.000179	0.000158	0.000137	0.000116	0.000095
1.700	0.000197	0.000185	0.000170	0.000154	0.000137	0.000118	0.000100	0.000082
1.750	0.000171	0.000160	0.000148	0.000134	0.000118	0.000103	0.000087	0.000071
1.800	0.000149	0.000139	0.000129	0.000116	0.000103	0.000089	0.000075	0.000062
1.850	0.000130	0.000122	0.000112	0.000101	0.000090	0.000078	0.000066	0.000054
1.900	0.000114	0.000107	0.000098	0.000089	0.000079	0.000068	0.000058	0.000047
1.950	0.000100	0.000094	0.000086	0.000078	0.000069	0.000060	0.000051	0.000042
2.000	0.000088	0.000083	0.000076	0.000069	0.000061	0.000053	0.000045	0.000037

Frequency	Wave directions (from, deg)							
(rad/s)	240.0	250.0	260.0	270.0	280.0	290.0	300.0	310.0
0.200	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.250	0.000027	0.000023	0.000019	0.000015	0.000011	0.000008	0.000005	0.000003
0.300	0.001777	0.001514	0.001251	0.000996	0.000757	0.000541	0.000354	0.000203
0.350	0.007340	0.006254	0.005168	0.004115	0.003127	0.002234	0.001463	0.000838
0.400	0.010915	0.009296	0.007678	0.006111	0.004642	0.003316	0.002172	0.001247
0.450	0.010846	0.009201	0.007569	0.006000	0.004542	0.003239	0.002130	0.001249
0.500	0.009299	0.007801	0.006343	0.004971	0.003724	0.002642	0.001757	0.001095
0.550	0.007583	0.006258	0.005000	0.003847	0.002835	0.001994	0.001350	0.000922
0.600	0.006045	0.004905	0.003846	0.002901	0.002098	0.001461	0.001010	0.000758
0.650	0.004748	0.003798	0.002929	0.002169	0.001540	0.001062	0.000749	0.000611
0.700	0.003695	0.002922	0.002224	0.001621	0.001134	0.000775	0.000556	0.000485
0.750	0.002864	0.002245	0.001691	0.001218	0.000841	0.000571	0.000416	0.000381
0.800	0.002220	0.001729	0.001292	0.000922	0.000630	0.000425	0.000313	0.000298
0.850	0.001726	0.001338	0.000993	0.000703	0.000477	0.000320	0.000238	0.000234
0.900	0.001349	0.001042	0.000770	0.000542	0.000365	0.000244	0.000183	0.000184
0.950	0.001061	0.000817	0.000602	0.000422	0.000283	0.000188	0.000142	0.000145
1.000	0.000841	0.000646	0.000474	0.000331	0.000221	0.000147	0.000112	0.000116
1.050	0.000671	0.000515	0.000377	0.000263	0.000175	0.000116	0.000088	0.000092
1.100	0.000540	0.000413	0.000302	0.000210	0.000139	0.000092	0.000071	0.000075
1.150	0.000437	0.000335	0.000244	0.000170	0.000112	0.000074	0.000057	0.000060
1.200	0.000357	0.000273	0.000199	0.000138	0.000091	0.000060	0.000046	0.000049
1.250	0.000293	0.000224	0.000163	0.000113	0.000075	0.000049	0.000038	0.000041
1.300	0.000243	0.000185	0.000135	0.000093	0.000062	0.000041	0.000031	0.000034
1.350	0.000202	0.000154	0.000112	0.000078	0.000051	0.000034	0.000026	0.000028
1.400	0.000169	0.000129	0.000094	0.000065	0.000043	0.000028	0.000022	0.000024
1.450	0.000143	0.000109	0.000079	0.000055	0.000036	0.000024	0.000018	0.000020
1.500	0.000121	0.000092	0.000067	0.000046	0.000030	0.000020	0.000015	0.000017
1.550	0.000103	0.000078	0.000057	0.000039	0.000026	0.000017	0.000013	0.000014
1.600	0.000088	0.000067	0.000049	0.000033	0.000022	0.000014	0.000011	0.000012
1.650	0.000075	0.000057	0.000042	0.000029	0.000019	0.000012	0.000010	0.000011
1.700	0.000065	0.000050	0.000036	0.000025	0.000016	0.000011	0.000008	0.000009
1.750	0.000056	0.000043	0.000031	0.000021	0.000014	0.000009	0.000007	0.000008
1.800	0.000049	0.000037	0.000027	0.000019	0.000012	0.000008	0.000006	0.000007
1.850	0.000043	0.000033	0.000024	0.000016	0.000011	0.000007	0.000005	0.000006
1.900	0.000038	0.000029	0.000021	0.000014	0.000009	0.000006	0.000005	0.000005
1.950	0.000033	0.000025	0.000018	0.000013	0.000008	0.000005	0.000004	0.000005
2.000	0.000029	0.000022	0.000016	0.000011	0.000007	0.000005	0.000004	0.000004

Frequency	Wave directions (from, deg)				
(rad/s)	320.0	330.0	340.0	350.0	360.0
0.200	0.000000	0.000000	0.000000	0.000000	0.000000
0.250	0.000001	0.000000	0.000000	0.000000	0.000001
0.300	0.000091	0.000023	0.000000	0.000023	0.000091
0.350	0.000377	0.000095	0.000000	0.000095	0.000378
0.400	0.000568	0.000155	0.000021	0.000171	0.000599
0.450	0.000624	0.000272	0.000205	0.000425	0.000925
0.500	0.000678	0.000518	0.000619	0.000979	0.001586
0.550	0.000723	0.000760	0.001030	0.001527	0.002235
0.600	0.000714	0.000878	0.001245	0.001805	0.002540
0.650	0.000651	0.000870	0.001259	0.001807	0.002498
0.700	0.000562	0.000786	0.001149	0.001642	0.002248
0.750	0.000467	0.000672	0.000989	0.001409	0.001919

0.800	0.000381	0.000558	0.000824	0.001172	0.001590
0.850	0.000307	0.000455	0.000674	0.000957	0.001296
0.900	0.000246	0.000368	0.000547	0.000775	0.001048
0.950	0.000198	0.000297	0.000442	0.000626	0.000846
1.000	0.000159	0.000240	0.000357	0.000506	0.000683
1.050	0.000128	0.000195	0.000290	0.000411	0.000553
1.100	0.000104	0.000159	0.000236	0.000334	0.000450
1.150	0.000085	0.000130	0.000193	0.000273	0.000368
1.200	0.000070	0.000107	0.000159	0.000225	0.000303
1.250	0.000058	0.000088	0.000131	0.000186	0.000250
1.300	0.000048	0.000073	0.000109	0.000155	0.000208
1.350	0.000040	0.000061	0.000091	0.000129	0.000174
1.400	0.000034	0.000051	0.000077	0.000109	0.000146
1.450	0.000028	0.000043	0.000065	0.000092	0.000123
1.500	0.000024	0.000037	0.000055	0.000078	0.000105
1.550	0.000020	0.000031	0.000047	0.000066	0.000089
1.600	0.000018	0.000027	0.000040	0.000057	0.000076
1.650	0.000015	0.000023	0.000035	0.000049	0.000066
1.700	0.000013	0.000020	0.000030	0.000042	0.000057
1.750	0.000011	0.000017	0.000026	0.000037	0.000049
1.800	0.000010	0.000015	0.000023	0.000032	0.000043
1.850	0.000009	0.000013	0.000020	0.000028	0.000037
1.900	0.000008	0.000012	0.000017	0.000024	0.000033
1.950	0.000007	0.000010	0.000015	0.000021	0.000029
2.000	0.000006	0.000009	0.000013	0.000019	0.000025

**** Motions at Ship CG in a Seaway ****

Ship speed : 5.150 m/s (10.000 knots, Froude number 0.150)
Ship heading (to) is in earth-fixed axes.
0 degrees for ship heading north, 90 degrees for ship heading east
RMS Displacements and Zero-crossing Periods

Ship heading	Surge		Sway		Heave		Roll		Pitch		Yaw	
(deg)	(m)	(s)	(m)	(s)	(m)	(s)	(deg)	(s)	(deg)	(s)	(deg)	(s)
0.0	0.85	15.9	0.67	12.0	0.96	11.6	4.38	9.5	1.05	9.4	0.81	11.7
15.0	0.83	15.8	0.67	11.9	0.96	11.3	4.35	9.4	1.09	9.0	0.78	11.5
30.0	0.80	15.5	0.66	11.8	0.97	11.1	4.31	9.4	1.12	8.7	0.75	11.3
45.0	0.76	15.1	0.66	11.7	0.98	10.8	4.28	9.3	1.16	8.4	0.71	11.1
60.0	0.71	14.7	0.65	11.5	0.99	10.6	4.25	9.2	1.19	8.2	0.67	10.8
75.0	0.66	14.1	0.65	11.4	0.99	10.4	4.23	9.1	1.22	8.0	0.63	10.4
90.0	0.62	13.5	0.65	11.3	1.00	10.2	4.21	9.1	1.25	7.9	0.59	10.1
105.0	0.57	12.9	0.64	11.2	1.01	10.1	4.21	9.0	1.27	7.8	0.56	9.8
120.0	0.54	12.3	0.64	11.1	1.01	10.0	4.21	9.0	1.28	7.8	0.54	9.6
135.0	0.51	11.9	0.64	11.1	1.01	10.0	4.22	9.0	1.29	7.7	0.53	9.5
150.0	0.50	11.8	0.64	11.1	1.01	10.0	4.24	9.0	1.28	7.8	0.54	9.5
165.0	0.51	11.9	0.64	11.1	1.01	10.0	4.27	9.0	1.27	7.8	0.56	9.7
180.0	0.54	12.2	0.64	11.1	1.00	10.1	4.30	9.1	1.25	8.0	0.58	9.9
195.0	0.57	12.7	0.64	11.2	1.00	10.3	4.33	9.1	1.23	8.1	0.62	10.2
210.0	0.62	13.3	0.65	11.3	0.99	10.4	4.37	9.2	1.19	8.3	0.66	10.6
225.0	0.66	13.9	0.65	11.5	0.98	10.7	4.40	9.3	1.16	8.5	0.70	10.8
240.0	0.71	14.4	0.66	11.6	0.97	10.9	4.43	9.4	1.12	8.9	0.74	11.1
255.0	0.76	14.9	0.66	11.7	0.97	11.2	4.45	9.5	1.09	9.2	0.77	11.3
270.0	0.80	15.3	0.66	11.8	0.96	11.4	4.47	9.5	1.06	9.6	0.80	11.5
285.0	0.83	15.6	0.67	11.9	0.95	11.7	4.47	9.6	1.03	9.9	0.82	11.7
300.0	0.85	15.8	0.67	12.0	0.95	11.8	4.47	9.6	1.02	10.2	0.83	11.8
315.0	0.87	16.0	0.67	12.1	0.95	11.9	4.46	9.6	1.01	10.3	0.84	11.8
330.0	0.87	16.0	0.67	12.1	0.95	11.9	4.44	9.6	1.02	10.1	0.84	11.8
345.0	0.87	16.0	0.67	12.0	0.95	11.8	4.41	9.5	1.03	9.8	0.82	11.7

Rudder RMS Deflections and Zero-crossing Periods
Values given for following rudders:
Rudder
Ship heading Deflection Tz

(deg)	(deg)	(s)
0.0	4.65	10.5
15.0	4.52	10.3
30.0	4.36	10.1
45.0	4.19	9.8
60.0	4.01	9.5
75.0	3.84	9.1
90.0	3.67	8.9
105.0	3.55	8.6
120.0	3.46	8.5
135.0	3.44	8.4
150.0	3.46	8.4
165.0	3.55	8.6
180.0	3.67	8.8
195.0	3.83	9.1
210.0	4.00	9.4
225.0	4.19	9.7
240.0	4.36	10.0
255.0	4.52	10.3
270.0	4.64	10.5
285.0	4.74	10.6
300.0	4.80	10.8
315.0	4.82	10.8
330.0	4.80	10.8
345.0	4.75	10.7

Seakeeping at Position on Ship

```
Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s
```

RMS Motions at Seakeeping Position

```
Label           : Bridge
Station         :     3.000
x wrt ship CG   :    43.739 m
y               :     2.000 m
z wrt baseline  :    12.000 m
z wrt ship CG   :     6.000 m
z wrt waterline :     7.800 m
Parameters for motion-induced interruptions
Lateral tipping coefficient      :     0.250
Longitudinal tipping coefficient :     0.170 s
Time of operation                :    60.000 s
```

Ship heading	*** Longitudinal ***			*** Lateral ***			*** Vertical ***			*** Relative Vertical ***		
	Disp	Tz	Acc	Disp	Tz	Acc	Disp	Tz	Acc	Disp	Tz	Vel
(deg)	(m)	(s)	(g)	(m)	(s)	(g)	(m)	(s)	(g)	(m)	(s)	(m/s)
0.0	2.30	49.4	0.013	0.80	10.6	0.036	1.33	10.0	0.074	0.80	6.7	0.078
15.0	0.88	19.5	0.013	0.80	10.4	0.037	1.36	9.6	0.079	0.84	6.3	0.085
30.0	1.94	44.2	0.013	0.81	10.2	0.038	1.39	9.3	0.085	0.88	6.1	0.093
45.0	0.77	18.3	0.013	0.81	10.1	0.039	1.43	9.0	0.091	0.92	5.9	0.101
60.0	1.48	36.8	0.012	0.81	9.9	0.040	1.46	8.8	0.096	0.96	5.7	0.108
75.0	0.63	16.7	0.012	0.81	9.7	0.041	1.50	8.6	0.101	1.00	5.6	0.114

90.0	0.98	27.2	0.012	0.81	9.6	0.042	1.53	8.5	0.105	1.03	5.6	0.119
105.0	0.50	14.7	0.012	0.81	9.5	0.043	1.55	8.4	0.107	1.05	5.6	0.122
120.0	0.65	19.7	0.012	0.81	9.4	0.043	1.56	8.3	0.109	1.07	5.6	0.124
135.0	0.44	13.6	0.012	0.81	9.4	0.043	1.57	8.3	0.109	1.08	5.6	0.124
150.0	0.85	26.4	0.012	0.81	9.4	0.043	1.57	8.4	0.108	1.08	5.6	0.123
165.0	0.48	14.8	0.012	0.81	9.4	0.043	1.56	8.5	0.105	1.06	5.7	0.120
180.0	1.33	39.5	0.012	0.80	9.5	0.042	1.54	8.6	0.102	1.04	5.8	0.116
195.0	0.60	17.1	0.012	0.80	9.6	0.041	1.52	8.7	0.098	1.01	5.9	0.110
210.0	1.81	48.9	0.012	0.80	9.7	0.040	1.48	8.9	0.092	0.98	6.1	0.104
225.0	0.74	18.9	0.012	0.80	9.9	0.039	1.45	9.2	0.087	0.94	6.3	0.096
240.0	2.21	53.7	0.012	0.80	10.1	0.038	1.41	9.5	0.081	0.90	6.5	0.088
255.0	0.86	20.0	0.013	0.80	10.3	0.037	1.38	9.8	0.075	0.86	6.8	0.081
270.0	2.47	55.3	0.013	0.80	10.5	0.036	1.35	10.1	0.070	0.82	7.2	0.073
285.0	0.94	20.5	0.013	0.80	10.6	0.035	1.32	10.4	0.066	0.79	7.5	0.068
300.0	2.57	54.8	0.013	0.80	10.7	0.035	1.30	10.6	0.063	0.77	7.7	0.064
315.0	0.97	20.5	0.013	0.80	10.8	0.035	1.29	10.7	0.063	0.76	7.6	0.064
330.0	2.52	52.8	0.013	0.80	10.8	0.035	1.29	10.6	0.065	0.76	7.4	0.066
345.0	0.95	20.2	0.013	0.80	10.7	0.035	1.31	10.3	0.069	0.78	7.0	0.071

Forces Relative to Local Axes and Motion-Induced Interruptions

MIIs given as rate for following duration : 60.0 s
Lateral tipping coefficient : 0.250
Longitudinal tipping coefficient : 0.170

Ship heading	***** Lateral *****			***** Longitudinal *****			Total
	Force estimator		MIIs	Force estimator		MIIs	MIIs
	RMS	Tz		RMS	Tz		
(deg)	(g)	(s)		(g)	(s)		
0.0	0.095	8.5	13.868	0.012	5.8	7.803	21.670
15.0	0.096	8.5	13.998	0.013	5.8	8.172	22.170
30.0	0.097	8.4	14.130	0.014	5.8	8.423	22.553
45.0	0.098	8.3	14.259	0.015	5.8	8.662	22.921
60.0	0.099	8.3	14.371	0.016	5.8	8.815	23.186
75.0	0.100	8.3	14.464	0.017	5.8	8.963	23.427
90.0	0.101	8.2	14.531	0.017	5.9	9.057	23.588
105.0	0.102	8.2	14.573	0.018	5.9	9.147	23.720
120.0	0.103	8.2	14.587	0.018	5.9	9.193	23.779
135.0	0.103	8.2	14.574	0.018	5.9	9.222	23.796
150.0	0.103	8.2	14.535	0.018	5.9	9.202	23.737
165.0	0.103	8.3	14.473	0.017	6.0	9.150	23.624
180.0	0.103	8.3	14.389	0.017	6.0	9.038	23.427
195.0	0.102	8.3	14.287	0.016	6.0	8.884	23.172
210.0	0.101	8.4	14.171	0.015	6.0	8.655	22.826
225.0	0.100	8.4	14.049	0.014	6.0	8.387	22.436
240.0	0.099	8.5	13.925	0.013	6.1	8.029	21.954
255.0	0.098	8.5	13.811	0.012	6.1	7.671	21.482
270.0	0.097	8.6	13.714	0.011	6.1	7.250	20.964
285.0	0.096	8.6	13.646	0.010	6.1	6.968	20.614
300.0	0.095	8.6	13.613	0.010	6.1	6.752	20.365
315.0	0.094	8.6	13.622	0.010	5.9	6.853	20.475
330.0	0.094	8.6	13.670	0.010	5.9	7.054	20.724
345.0	0.095	8.6	13.756	0.011	5.8	7.461	21.217

Wetness Calculations for Position Above Waterline

Wetness probability is given as probability per wave encounter.

Elevation relative to calm waterline : 7.800 m

Ship heading	** Relative vertical motion **			Wetness	
	RMS disp	Tz	RMS vel	P(wet)	Rate
(deg)	(m)	(s)	(m/s)	per enc	per hour
0.0	0.808	6.7	0.762	0.000000	0.000000

15.0	0.844	6.3	0.838	0.000000	0.000000
30.0	0.884	6.1	0.914	0.000000	0.000000
45.0	0.926	5.9	0.990	0.000000	0.000000
60.0	0.966	5.7	1.058	0.000000	0.000000
75.0	1.004	5.6	1.117	0.000000	0.000000
90.0	1.035	5.6	1.163	0.000000	0.000000
105.0	1.059	5.6	1.196	0.000000	0.000000
120.0	1.075	5.6	1.214	0.000000	0.000000
135.0	1.082	5.6	1.217	0.000000	0.000000
150.0	1.080	5.6	1.205	0.000000	0.000000
165.0	1.068	5.7	1.178	0.000000	0.000000
180.0	1.048	5.8	1.136	0.000000	0.000000
195.0	1.019	5.9	1.082	0.000000	0.000000
210.0	0.985	6.1	1.017	0.000000	0.000000
225.0	0.945	6.3	0.945	0.000000	0.000000
240.0	0.904	6.5	0.868	0.000000	0.000000
255.0	0.862	6.8	0.792	0.000000	0.000000
270.0	0.825	7.2	0.721	0.000000	0.000000
285.0	0.792	7.5	0.666	0.000000	0.000000
300.0	0.771	7.7	0.630	0.000000	0.000000
315.0	0.761	7.6	0.626	0.000000	0.000000
330.0	0.765	7.4	0.648	0.000000	0.000000
345.0	0.781	7.0	0.697	0.000000	0.000000

C.4 Format of Directional Wave Spectrum Input File

Record (a), Beginning Record

"begin inputDirSpectrum"(1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for spectrum. This can include spaces.

Record (c), Significant Wave Height and Characteristic Wave Period

"hsTchar", hs, tChar (1 character string, 2 floats)

"hsTchar"	Record tag.
hs	Significant wave height (m)
tChar	Characteristic wave period (s)

Record (d1), Range of Wave Frequencies

One of Records (d1) or (j2) must be given.

"waveFreqRange", waveFreqMin, waveFreqMax, waveFreqInc (1 character string, 3 floats)

"waveFreqRange"	Record tag.
waveFreqMin	Minimum wave frequency (rad/s).
waveFreqMax	Maximum wave frequency (rad/s).
waveFreqInc	Increment for wave frequency (rad/s).

Record (d2), Wave Frequencies

One of Records (d2) or (d2) must be given.

"waveFreqs", waveFreqs (1 character string, array of floats)

"waveFreqs"	Record tag.
waveFreqs	Array of increasing incident wave frequencies (rad/s).

Record (e1), Wave Direction Range

One of Records (e1) or (e2) must be given.

"waveDirFromRange", waveDirFromDegMin, waveDirFromDegMax, waveDirFromDegInc (1 character string, 3 floats)

"waveDirFromRange"	Record tag.
waveDirFromDegMin	Minimum wave direction (deg).
waveDirFromDegMax	Maximum wave direction (deg).
waveDirFromDegInc	Wave direction increment (deg).
Note:	Wave directions are given using a convention of 0° for waves from north, 90° for waves from east.

Record (e2), Wave Directions

One of Records (e1) or (e2) must be given.

"waveDirsFrom", waveDirsFromDeg (1 character string, array of floats)

"waveDirsFrom"	Record tag.
waveDirsFromDeg	Wave directions for integration of ship motion spectrum. Wave directions are given using a convention of 0° for waves from north, 90° for waves from east.

Record (f), Wave Energy Spectral Densities for Specified Wave Frequencies.

nWaveFreq Records must be given, where nWaveFreq is the number of wave frequencies specified by Record (d1) or (d2).

"energyDensities", waveFreq, energyDensitiesDirDeg (1 character string, 1 + nWaveDir floats)

"energyDensities"	Record tag.
waveFreq	Wave frequency for energy densities within Record. This value must be consistent with wave frequencies specified by Record (d1) or (d2).
energyDensitiesDirDeg	Energy densities (m2/(rad/s)/deg) for frequency waveFreq and wave directions specified in Record (e1) or (e2).

Record (g), End Record

"end inputDirSpectrum"(1 character string with 2 words)

Annex D: Files for Producing Time Series of Ship Motions based on Response Amplitude Operators

D.1 Format of Input File for SM3DTimeSeriesFromRaos

Record (a), Beginning Record

"begin SM3DTimeSeriesFromRaos"(1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for run. This can include spaces.

Record (c), Ship Dimensions

"shipDimensions", lpp, stationAP, xCGAftFP, draftBlMid trimBlStern, shipKG (1 character string, 6 floats)

"shipDimensions"	Record tag.
lpp	Ship length between perpendiculars.
stationAP	Station number for aft perpendicular (typically 20.0).
xCGAftFP	Distance from fore perpendicular to longitudinal centre of gravity (LCG) (m).
draftBlMid	Draft of baseline at midships (m).
trimBlStern	Trim of baseline by stern (m).
shipKG	Height of centre of gravity above baseline (m).

Record (d), Motion RAO Database File Name

"motionRAODBFileName", motionRAODBFileName (2 character strings)

"motionRAODBFileName"	Record tag.
motionRAODBFileName	Name of file with ship motion response amplitude operators. This file is typically built using SM3DSeakeepRegular or SM3DSeakeepRandom.

Record (e), Fixed Seaway File Name

"fixedSeawayFileName", fixedSeawayFileName (2 character strings)

"fixedSeawayFileName"	Record tag.
fixedSeawayFileName	Name of file with seaway in earth-fixed axes. This file is typically built using SM3DBuildSeaway.

Record (e1), Motion Axes Output Option

"motionAxesOutputOption", motionAxesOutputOption (2 character strings)

"motionAxesOutputOption"	Record tag.
motionAxesOutputOption	transEarth - Output values are given in translating earth axes. For seakeeping positions, values are given relative to their position when the ship is moving at speed in calm water. earthFixed - Output values are given in earth-fixed axes.

Record (e2), Ship Motion Output Options

"shipOutputOptions", outDispShipOption, outVelShipOption, outAccShipOption (4 character strings)

"shipOutputOptions"	Record tag.
outDispShipOption	outDisp - Displacements at the ship CG are written to output. noOutDisp - No displacements are written to output.
outVelShipOption	outVel - Velocities at the ship CG are written to output. noOutVel - No velocities are written to output.
outAccShipOption	outAcc - Accelerations at the ship CG are written to output. noOutAcc - No accelerations are written to output.

Record (f), Beginning of Seakeeping Position Data

This record is optional.

"begin seakeepPositions" (1 character string with 2 words)

Note: If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (f1) to (f3) giving seakeeping position parameters. Record (g) must follow at the end of all seakeeping position data.

Record (f1), Seakeeping Position Label

This record is required if a seakeeping position is being specified.

"labelPos", labelPos (2 character strings)

"labelPos"	Record tag.
labelPos	Label for seakeeping position. This can include spaces.

Record (f2), Seakeeping Position Location

This record is required if a seakeeping position is being specified.

(1 character string, 3 floats)

"locationPos"	Record tag.
stationPos	Station for seakeeping position. Station 0 is at the fore perpendicular.
yPos	Lateral coordinate (+ port) relative to ship centreline (m).
zBlPos	Vertical coordinate (+ up) relative to ship baseline (m).

Record (f3), Seakeeping Position Output Options

This record is required if a seakeeping position is being specified.

"posOutputOptions", outDispPosOption, outVelPosOption, outAccPosOption, outRelMotionPosOption (5 character strings)

"posOutputOptions"	Record tag.
outDispPosOption	outDisp - Displacements at position are written to output.
	noOutDisp - No displacements are written to output.
outVelPosOption	outVel - Velocities at position are written to output.
	noOutVel - No velocities are written to output.
outAccPosOption	outAcc - Accelerations at position are written to output.
	noOutAcc - No accelerations are written to output.
outRelMotionPosOption	outRelMotion - Relative vertical displacements and velocities at position are written to output.
	noOutRelMotion - No relative vertical displacements or velocities at position are written to output.

Record (g), End of Seakeeping Position Data

This record is required if Record (f) is present.

"end seakeepPositions" (1 character string with 2 words)

Record (h1), Ship Speed

Either this record or Record (h2) must be given.

"speed", speed (1 character string, 1 float)

"speed"	Record tag.
speed	Ship speed (m/s).

Record (h2), Ship Speed in Knots

Either this record or Record (h1) must be given.

"speedKnots", speedKnots (1 character string, 1 float)

"speedKnots"	Record tag.
speedKnots	Ship speed (knots).

Record (i), Ship Heading

"heading", shipHeadingToMeanDeg (1 character string, 1 float)

"heading"	Record tag.
shipHeadingToMeanDeg	Mean ship heading (to, deg). The heading is 0° for the ship heading north, and 90° for the ship heading east.

Record (j), Initial Ship Position

"shipPosition0", xf0, yf0 (1 character string, 2 floats)

"shipPosition0"	Record tag.
xf0	Initial x^f position of ship at time t0 (m).
yf0	Initial y^f position of ship at time t0 (m).

Record (k), Time Parameters

"timeParameters", t0, tEnd, dt (1 character string, 3 floats)

"timeParameters"	Record tag.
t0	Time at start of time series(s).
tEnd	Time at end of time series(s).
dt	Time increment (s).

Record (l), End Record

"end SM3DTimeSeriesFromRaos"(1 character string with 2 words)

D.2 Sample Input File for SM3DTimeSeriesFromRaos

```
begin SM3DTimeSeriesFromRAOs
label Generic frigate in sea state 5
shipDimensions 120.0 20.0 61.739 4.20 0.0 6.0
motionRAODBFileName genFrigRao.pkl
fixedSeawayFileName bretSeaState5.pkl
motionAxesOutputOption transEarth
shipOutputOptions outDisp noOutVel noOutAcc
speedKnots 20.0
heading 120.0
shipPosition0 0.0 0.0
timeParameters 0.0 100.0 1.0
end SM3DSeakeepRandom
```

D.3 Sample Output File for SM3DTimeSeriesFromRaos

```
Program SM3DTimeSeriesFromRAOs
ShipMo3D library Version 1.0c - 26 November 2007
Time : Wed Feb 06 16:19:00 2008
Run label:
Generic frigate in sea state 5

**** ECHO OF USER INPUT ****

Ship Dimensions
Length between perpendiculars           :   120.000 m
Station number of aft perpendicular     :    20.000
Distance from fore perpendicular to LCG :    61.739
Draft of baseline at midships           :     4.200 m
Trim of baseline by stern               :     0.000 m
Height of CG above baseline             :     6.000 m

File name with ship motion RAOs :  genFrigRao.pkl

File name with seaway in earth-fixed axes :  bretSeaState5.pkl

Motion axes output option : transEarth

Ship Motion Output Options
Displacement option : outDisp
Velocity option     : noOutVel
Acceleration option : noOutAcc

Ship speed :    20.000 knots

Ship heading (to) :   120.000

Initial Ship Position in Earth-fixed Axes
xf0 :     0.000 m
yf0 :     0.000 m

Time Parameters
Start time     :     0.000 s
End time       :   100.000 s
Time increment :     1.000 s

**** SEAKEEPING POSITION TRIM CONDITIONS ****


Displacements at Ship CG in Translating Earth Axes
Surge + forward
Sway + port
Heave + up
Roll + port side up
Pitch + bow down
Yaw + bow to port
          t        Surge         Sway        Heave         Roll        Pitch          Yaw
        (s)          (m)          (m)          (m)        (deg)        (deg)        (deg)
      0.000        1.246       -0.194        0.620      -14.466       -1.269       -0.872
      1.000        1.409       -0.471        0.175      -17.371       -1.464       -2.145
      2.000        1.326       -0.665       -0.302      -16.837       -1.388       -2.978
      3.000        1.008       -0.735       -0.724      -13.013       -1.056       -3.216
      4.000        0.512       -0.660       -1.015       -6.689       -0.531       -2.825
      5.000       -0.077       -0.450       -1.123        0.865        0.087       -1.896
      6.000       -0.653       -0.137       -1.029        8.156        0.682       -0.623
      7.000       -1.115        0.223       -0.751       13.769        1.145        0.734
```

8.000	-1.384	0.562	-0.342	16.637	1.390	1.906
9.000	-1.416	0.817	0.123	16.245	1.375	2.664
10.000	-1.211	0.935	0.559	12.725	1.107	2.863
11.000	-0.813	0.889	0.887	6.812	0.640	2.474
12.000	-0.298	0.681	1.050	-0.307	0.064	1.580
13.000	0.235	0.343	1.019	-7.234	-0.510	0.367
14.000	0.689	-0.070	0.806	-12.637	-0.974	-0.924
15.000	0.984	-0.488	0.451	-15.505	-1.244	-2.036
16.000	1.070	-0.839	0.023	-15.339	-1.272	-2.753
17.000	0.940	-1.067	-0.398	-12.234	-1.057	-2.936
18.000	0.627	-1.134	-0.733	-6.847	-0.646	-2.551
19.000	0.197	-1.035	-0.924	-0.256	-0.119	-1.672
20.000	-0.262	-0.791	-0.938	6.254	0.420	-0.468
21.000	-0.661	-0.450	-0.777	11.449	0.870	0.837
22.000	-0.923	-0.076	-0.475	14.376	1.145	2.000
23.000	-0.999	0.266	-0.093	14.539	1.198	2.811
24.000	-0.879	0.519	0.295	11.981	1.022	3.131
25.000	-0.589	0.645	0.615	7.255	0.655	2.911
26.000	-0.187	0.635	0.809	1.307	0.170	2.204
27.000	0.246	0.502	0.842	-4.715	-0.340	1.151
28.000	0.628	0.287	0.712	-9.689	-0.776	-0.051
29.000	0.886	0.040	0.447	-12.725	-1.059	-1.184
30.000	0.972	-0.181	0.102	-13.328	-1.137	-2.052
31.000	0.872	-0.332	-0.256	-11.471	-1.001	-2.513
32.000	0.608	-0.382	-0.557	-7.590	-0.681	-2.507
33.000	0.233	-0.324	-0.744	-2.476	-0.240	-2.059
34.000	-0.182	-0.176	-0.783	2.880	0.234	-1.276
35.000	-0.558	0.027	-0.669	7.481	0.653	-0.319
36.000	-0.825	0.238	-0.426	10.510	0.939	0.627
37.000	-0.936	0.407	-0.103	11.476	1.042	1.389
38.000	-0.873	0.495	0.237	10.286	0.946	1.834
39.000	-0.652	0.479	0.527	7.249	0.677	1.898
40.000	-0.317	0.359	0.714	2.999	0.288	1.587
41.000	0.069	0.152	0.761	-1.635	-0.144	0.980
42.000	0.433	-0.104	0.663	-5.788	-0.536	0.206
43.000	0.712	-0.362	0.439	-8.720	-0.816	-0.579
44.000	0.856	-0.577	0.133	-9.948	-0.936	-1.226
45.000	0.847	-0.709	-0.195	-9.316	-0.877	-1.613
46.000	0.692	-0.736	-0.484	-7.015	-0.656	-1.675
47.000	0.428	-0.656	-0.681	-3.527	-0.321	-1.408
48.000	0.108	-0.483	-0.749	0.470	0.063	-0.868
49.000	-0.204	-0.251	-0.679	4.238	0.422	-0.162
50.000	-0.450	-0.001	-0.485	7.109	0.690	0.578
51.000	-0.584	0.224	-0.206	8.605	0.820	1.216
52.000	-0.585	0.387	0.107	8.514	0.795	1.640
53.000	-0.457	0.465	0.395	6.912	0.623	1.779
54.000	-0.226	0.450	0.609	4.143	0.344	1.617
55.000	0.062	0.351	0.711	0.744	0.014	1.191
56.000	0.353	0.192	0.687	-2.662	-0.304	0.588
57.000	0.594	0.006	0.546	-5.473	-0.552	-0.080
58.000	0.746	-0.173	0.317	-7.217	-0.688	-0.690
59.000	0.785	-0.312	0.042	-7.630	-0.694	-1.134
60.000	0.710	-0.387	-0.227	-6.691	-0.575	-1.338
61.000	0.540	-0.386	-0.447	-4.620	-0.362	-1.275
62.000	0.310	-0.310	-0.582	-1.831	-0.100	-0.966
63.000	0.063	-0.173	-0.616	1.154	0.160	-0.478
64.000	-0.158	0.005	-0.549	3.795	0.371	0.090
65.000	-0.317	0.197	-0.401	5.632	0.496	0.628
66.000	-0.393	0.376	-0.202	6.364	0.521	1.036
67.000	-0.380	0.518	0.010	5.901	0.451	1.239
68.000	-0.289	0.605	0.201	4.370	0.308	1.206
69.000	-0.143	0.629	0.343	2.089	0.127	0.951
70.000	0.028	0.587	0.419	-0.495	-0.053	0.532
71.000	0.193	0.488	0.427	-2.892	-0.197	0.037

72.000	0.327	0.346	0.375	-4.660	-0.280	-0.430
73.000	0.414	0.178	0.282	-5.482	-0.296	-0.774
74.000	0.448	0.009	0.169	-5.232	-0.250	-0.924
75.000	0.434	-0.140	0.055	-3.986	-0.163	-0.851
76.000	0.387	-0.247	-0.045	-2.015	-0.062	-0.569
77.000	0.323	-0.295	-0.121	0.274	0.026	-0.140
78.000	0.258	-0.272	-0.173	2.417	0.079	0.347
79.000	0.202	-0.178	-0.204	3.981	0.087	0.784
80.000	0.163	-0.017	-0.222	4.650	0.053	1.075
81.000	0.138	0.195	-0.231	4.290	-0.010	1.152
82.000	0.120	0.432	-0.234	2.978	-0.077	0.986
83.000	0.103	0.664	-0.230	0.985	-0.127	0.603
84.000	0.077	0.860	-0.212	-1.274	-0.139	0.072
85.000	0.041	0.990	-0.173	-3.322	-0.102	-0.504
86.000	-0.002	1.031	-0.107	-4.716	-0.021	-1.008
87.000	-0.044	0.972	-0.011	-5.143	0.088	-1.334
88.000	-0.072	0.817	0.108	-4.484	0.201	-1.410
89.000	-0.073	0.585	0.239	-2.848	0.288	-1.212
90.000	-0.038	0.306	0.360	-0.554	0.322	-0.773
91.000	0.038	0.021	0.449	1.928	0.286	-0.178
92.000	0.148	-0.226	0.484	4.070	0.178	0.453
93.000	0.277	-0.398	0.448	5.397	0.011	0.987
94.000	0.402	-0.468	0.336	5.586	-0.185	1.306
95.000	0.498	-0.423	0.155	4.547	-0.373	1.331
96.000	0.539	-0.273	-0.070	2.443	-0.513	1.043
97.000	0.507	-0.043	-0.309	-0.325	-0.571	0.485
98.000	0.398	0.228	-0.519	-3.195	-0.527	-0.239
99.000	0.219	0.493	-0.664	-5.558	-0.380	-0.989
100.000	-0.007	0.705	-0.713	-6.879	-0.151	-1.609

Statistics of displacements at ship CG in translating earth axes

	Mean	Dev	Max	Min	Tz (s)
Surge (m)	0.088	0.603	1.409	-1.416	15.800
Sway (m)	0.043	0.505	1.031	-1.134	15.167
Heave (m)	-0.026	0.525	1.050	-1.123	15.600
Roll (deg)	-0.264	7.838	16.637	-17.371	14.333
Pitch (deg)	-0.035	0.659	1.390	-1.464	13.500
Yaw (deg)	-0.039	1.503	3.131	-3.216	14.167

Annex E: Files for Producing Polar Plots of Ship Responses

E.1 Format of Input File for SM3DPolarPlot

Record (a), Beginning Record

"begin SM3DPolarPlot"(1 character string with 2 words)

Record (b), Run Label

"label", label (2 character strings)

"label"	Record tag.
label	Label for run. This can include spaces.

Record (c), Title Option

This record is optional.

"titleOption", titleOption (2 character strings)

"titleOption"	Record tag.
titleOption	Option for plotting label from Record (b) as the plot title: title - The plot includes a title. noTitle - No title is given on the plot.
Note:	If this record is omitted, then the title is drawn by default.

Record (d), Speed Units

"speedUnitLabel", speedUnitLabel (2 character strings)

"speedUnitLabel"	Record tag.
speedUnitLabel	Character string giving units for ship speed (typically "knots"). This string should not include parentheses, which are added during plotting. The input speed units are used for both plotting and for interpolation of input response data.

Record (e), Plot Speed Maximum, Increment, and Offset

"speedsPlot", speedMax, speedInc, speedOffset (1 character string, 3 floats)

"speedsPlot"	Record tag.
speedMax	Maximum speed on the plot.
speedInc	Speed increment between circles on the plot.
speedOffset	Offset from center of plot of speed zero. This offset is given in speed units. A value of approximately 20 percent of speedMax is recommended (e.g., a value of 5 when speedMax = 30).
Note:	The units for ship speeds are specified in Record (d).

Record (f), Plot Heading Increment

This record is optional.

"seaDirIncrement", seaDirDegInc (1 character string, 1 float)

"seaDirIncrement"	Record tag.
seaDirDegInc	Relative sea direction increment (deg) for radial axis lines.
Note:	If this record is omitted, then a default value of 30 degrees is used.

Record (g), Response Shaded Scale Parameters

"respScaleParameters", responseScaleMin, responseScaleMax, responseScaleInc (1 character string, 3 floats)

"shadeParameters"	Record tag.
responseScaleMin	Shaded scale minimum value.
responseScaleMax	Shaded scale maximum value.
responseScaleInc	Shaded scale increment value.

Record (h), Colour Table

This record is optional.

"colourTable", colourTable (2 character strings)

"colourTable"	Record tag.
colourTable	The colour table used for representing responses. greenYellowRed - Green for minimum values and red for maximum values, with yellow for intermediate values. grey - Black for minimum values and white for maximum values. small - 8 colours. vga - 16 colours. rain - 256 rainbow colours. spec - 256 spectrum colours, with more violet colours than rain. rrain - Reverse rainbow. rspec - Reverse spectrum. rgrey - Reverse grey.
Note:	If this record is omitted, then greenYellowRed is used by default.

Record (i), Response Label

This record is optional.

"responseLabel", responseLabel (2 character strings)

"responseLabel"	Record tag.
responseLabel	Label for shaded response legend.
Note:	If this record is omitted, then no shaded response legend label is drawn.

Record (j), Plot Resolution

This record is optional.

"resolution", resolution (1 character string, 1 integer)

"resolution"	Record tag.
resolution	Number of pixels for making plot (maximum 1000).
Note:	If this record is omitted, then a default value of 300 is used.

Record (k), Response Scale Option

This record is optional.

"scaleOption", scaleOption (2 character strings)

"scaleOption"	Record tag.
scaleOption	Option for shaded response scale: linear - Linear scale. log - Logarithmic (base 10) scale.
Note:	If this record is omitted, then a linear scale is used by default.

Record (l), Response Legend Option

This record is optional.

"responseLegendOption", responseLegendOption (2 character strings)

"responseLegendOption"	Record tag.
responseLegendOption	Option for plotting shaded bar legend: responseLegend - The response legend is drawn. noResponseLegend - No response legend is drawn.
Note:	If this record is omitted, then the response legend is drawn by default.

Record (m), Suppress Text Option

This record is optional.

"suppressTextOption", suppressTextOption (2 character strings)

"suppressTextOption"	Record tag.
suppressTextOption	Option for suppressing plot text. suppressText - No text is drawn on the plot. This feature can be useful if text is to be added by an external image editing program. keepText - Text is drawn.
Note:	If this record is omitted, then all text is drawn by default.

Record (n), Axis Length

This record is optional.

"axisLength", axisLengthmm (1 character string, 1 float)

"axisLength"	Record tag.
axisLengthmm	Axis length (mm).
Note:	If this record is omitted, then a default axis length of 80 mm is used.

Record (o), Heading Symmetry Option

This record is optional.

"seaDirSymmetryOption", seaDirSymmetryOption (2 character string)

"seaDirSymmetryOption"	Record tag.
seaDirSymmetryOption	Option for heading symmetry.
	seaDirSymmetry - Plot responses are symmetric with respect to heading (i.e., response at relative sea direction β_s is equal to response at heading $360^\circ - \beta_s$).
	noSeaDirSymmetry - Plot responses are not necessarily symmetric with respect to heading.
Note:	If this record is omitted, then a default option of seaDirSymmetry is used.

Record (p), Plot Output Option

This record is optional.

"plotOutOption", plotOutOption (2 character strings)

"plotOutOption"	Record tag.
plotOutOption	Option for making plots:
	screenFile - Plots are both plotted on the screen and to a file (default).
	screen - Plots are only plotted on the screen.
	file - Plots are only written to a file.

Record (q), Output File Format

This record is optional.

"fileFormat", fileFormat (2 character string)

"fileFormat"	Record tag.
fileFormat	Format of output file. Valid formats are: bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.
Note:	If this record is omitted, then a default option of png is used.

Record (r), Output File Name

This record is optional.

"fileName", fileName (2 character string)

"fileName"	Record tag.
fileName	Name of output file.
Note:	If this record is omitted, then a default option of polarPlot.ext is used, where ext is the file name extension according to Record (q).

Record (s1), Ship Speed Range for Input Responses

Either Record (s1) or (s2) must be given.

"speedRespRange", speedRespMin, speedRespMax, speedRespInc (1 character string, 3 floats)

"speedRespRange"	Record tag.
speedRespMin	Minimum ship speed for input responses.
speedRespMax	Maximum ship speed for input responses.
speedRespInc	Increment for ship speed for input responses.
Note:	The units for ship speeds are specified in Record (d).

Record (s2), Ship Speeds for Input Responses

Either Record (s1) or (s2) must be given.

"speedsResp", speedsResp (1 character string, array of floats)

"speedsResp"	Record tag.
speedsResp	Array of ship speeds for input responses.
Note:	The units for ship speeds are specified in Record (d).

Record (t1), Range of Sea Directions Relative to the Ship for Input Responses

One of Records (t1) or (t2) must be given.

"seaDirDegRespRange", seaDirDegRespMin, seaDirDegRespMax, seaDirDegRespInc (1 character string, 3 floats)

"seaDirDegRespRange"	Record tag.
seaDirDegRespMin	Minimum sea direction β_s relative to ship for input responses (deg). This value must be 0.0.
seaDirDegRespMax	Maximum sea direction β_s relative to ship for input responses (deg). If the lateral symmetry option for Record (o) then this value must be 180 degrees. If the lateral symmetry option is not used, then this value must be 360 degrees.
seaDirDegRespInc	Increment sea direction relative to ship for input responses (deg).

Record (t2), Sea Directions Relative to the Ship for Input Responses

One of Records (t1) or (t2) must be given.

"seaDirsDegResp", seaDirsDegResp (1 character string, array of floats)

"seaDirsDegResp"	Record tag.
seaDirsDegResp	Array of sea directions β_s relative to the ship for input responses (deg) . The minimum value must be 0.0. If the lateral symmetry option for Record (o) then the last value must be 180 degrees. If the lateral symmetry option is not used, then the last value must be 360 degrees.

Record (u), Beginning of Input Ship Responses

"begin responses"(1 character string with 2 words)

Record (v), Input Ship Responses

This record must be repeated nSeaDirResp times, where nSeaDirResp is the number of sea directions for input responses based on Record (t1) or (t2).

seaDirDegResp, responsesSeaDir (1 float, nSpeedResp floats)

seaDirDegResp	Relative sea direction (deg). Values in successive input records must correspond with successive values according to Record (t1) or (t2).
responsesSeaDir	Array of responses for relative sea direction seaDirDegResp. There must be nSpeedResp input values, where nSpeedResp is the number of input response speeds according to Record (s1) or (s2).

Record (w), End of Input Ship Responses

"end responses"(1 character string with 2 words)

Record (x), End of Polar Plot Data

"end SM3DPolarPlot"(1 character string with 2 words)

E.2 Sample Input File for SM3DPolarPlot

```
begin SM3DPolarPlot
label Sample plot
speedUnitLabel knots
speedsPlot 30.0 10.0 5.0
respScaleParameters 0.0 100.0 20.0
responseLabel Response
plotOutOption screenFile
fileFormat png
speedRespRange 0.0 30.0 10.0
seaDirDegRespRange 0.0 180.0 90.0
begin responses
     0.0  0.0 10.0 20.0 30.0
    90.0 30.0 40.0 50.0 60.0
   180.0 60.0 70.0 80.0 100.0
end responses
end SM3DPolarPlot
```

E.3 Sample Output File for SM3DPolarPlot

```
Program SM3DPolarPlot
ShipMo3D library Version 1.0c - 26 November 2007
Time : Wed Feb 06 16:19:16 2008
Run title:
Sample plot

**** ECHO OF USER INPUT ****


Title option :  title

Speed unit label : knots

Speed scale settings
Maximum                       :    30.000
Increment                     :    10.000
Offset of 0 speed from centre :     5.000

Sea direction increment for radial scale :      30.0 degrees

Response shaded scale parameters
Minimum response   :  0.0
Maximum response   :  100.0
Increment          :  20.0

Colour table : greenYellowRed

Response label : Response

Resolution (number of pixels) : 300

Response scale option : linear

Response legend option : responseLegend

Suppress text option : keepText

Axis length :      80.0 mm

Sea direction symmetry option :  seaDirSymmetry

File format option :  png
```

```
File name :  polarPlot.png

Ship speeds for input responses, units of knots :
   0.000   10.000   20.000   30.000

Relative sea directions (degrees) for input responses:
   0.000   90.000  180.000
```

E.4 Sample Output Plot for SM3DPolarPlot

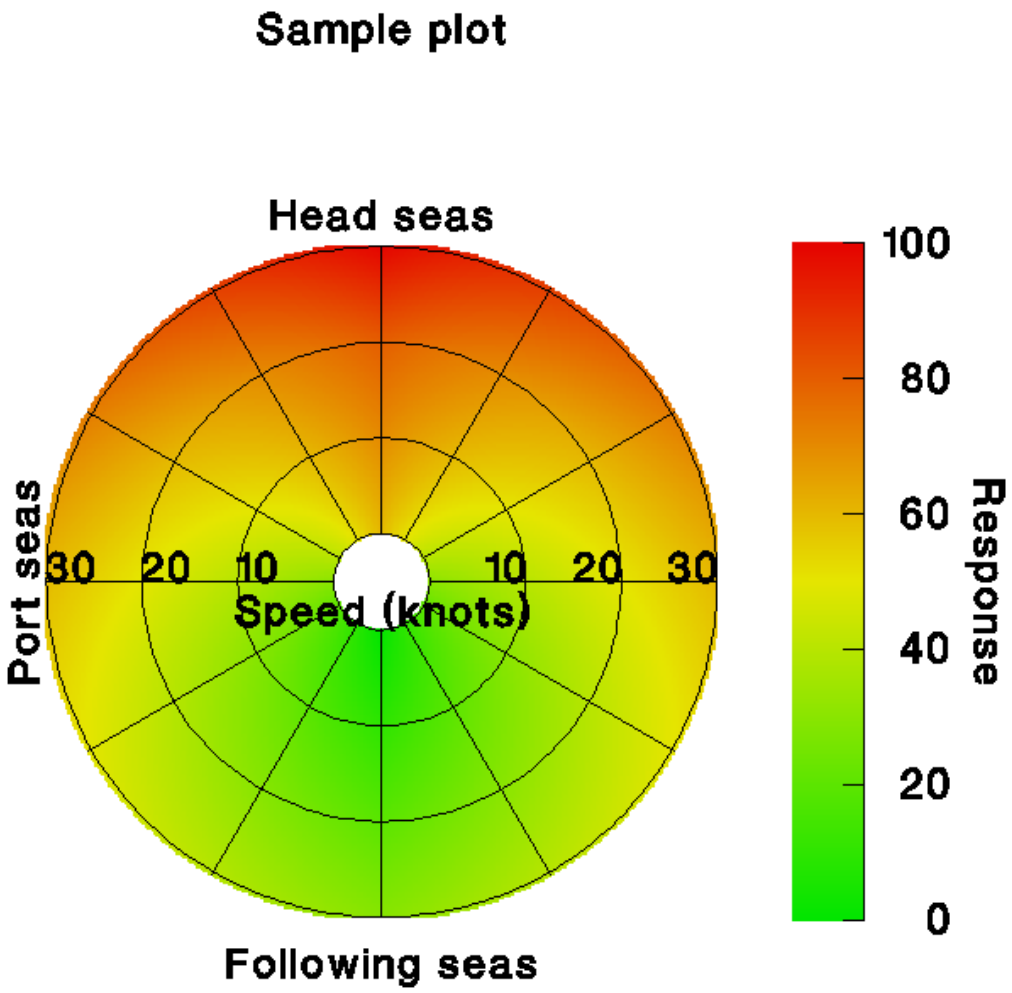

Figure E.1: *Sample Output Plot for SM3DPolarPlot*

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